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Overview of Invited Talks and Sessions

(Lecture halls H 1058, H 2013, EB 107, EB 202, EB 301, and EB 407; Poster A, C, and D)

Invited Talks

MA 3.1	Mon	9:30–10:00	H 2013	**Effects of Magnetization Inertia in Spin Dynamics** — •Anna Semisalova
MA 6.1	Mon	9:30–10:00	EB 301	**Studying single molecule magnets for quantum technologies** — •Wolfgang Wernsdorfer
MA 9.1	Mon	15:00–15:30	H 2013	**Optical control of 4f orbital state in rare-earth metals** — •N. Thielemann-Kühn, T. Amrhein, W. Bronsch, S. Jana, N. Pontius, R. Y. Engel, P. S. Miedema, D. Legut, K. Carva, U. Atxitia, B. E. van Kuiken, M. Teichmann, R. E. Carley, L. Mercadier, A. Yaroslavtsev, G. Mercurio, L. Le Guyader, N. Agarwal, R. Gort, A. Scherz, S. Dziarzhytski, G. Brenner, F. Pressacco, R.-P. Wang, J. O. Schunck, M. Sinha, M. Beye, G. S. Chiuzbăian, P.. Oppeneer, M. Weinelt, C. Schüssler-Langeheine
MA 14.1	Tue	9:30–10:00	H 1058	**Neutron scattering studies of spin-freezing phenomena at quantum phase transitions** — •Christian Pfleiderer
MA 14.2	Tue	10:00–10:30	H 1058	**Frustrations, glassiness and complexity of spin systems with large spatial dimension** — •Mikhail Katsnelson
MA 14.3	Tue	10:30–11:00	H 1058	**Self-Induced Spin Glass Phase and Thermally Induced Order in dhcp Nd** — •Anders Bergman
MA 14.6	Tue	11:45–12:15	H 1058	**Frustrated Quantum Devices: Pathways to leverage exotic order in novel spintronic technologies** — •James Analytis
MA 14.9	Tue	12:45–13:15	H 1058	**New Frontiers in Artificial Spin Ice: Phase Transitions in Two and Three Dimensions** — •Gavin M. Macauley, Luca Berchialla, Aleksandra Pac, Tianyue Wang, Armin Kleibert, Valerio Scagnoli, Peter M. Derlet, Laura J. Heyrderman
MA 21.1	Wed	9:30–10:00	H 1058	**Altermagnets: An unconventional magnetic class** — •Tomas Jungwirth
MA 21.2	Wed	10:00–10:30	H 1058	**Experimental evidence of time-reversal symmetry breaking in altermagnetic RuO_2** — •O. Fedchenko, J. Minar, A. Akashdeep, S.W. D'Souza, D. Vasilyev, O. Tkach, L. Odenbreit, Y. Lytvynenko, Q. Nguyen, D. Kutnyakhov, N. Wind, L. Wenthaus, M. Scholz, K. Rossnagel, M. Hoesch, M. Aeschlimann, B. Stadtmüller, M. Kläui, G. Schönhense, T. Jungwirth, A. Birk Hellenes, G. Jakob, L. Šmejkal, J. Sinova, H.-J. Elmers
MA 21.7	Wed	11:45–12:15	H 1058	**Is my altermagnet ferromagneto-octupolar or ferromagneto-triakontadipolar (and does it matter)?** — •Nicola Spaldin
MA 21.8	Wed	12:15–12:45	H 1058	**Negative critical current in an altermagnet Josephson junction** — •Carlo Beenakker
MA 22.1	Wed	9:30–10:00	H 2013	**Emergence of intrinsic antiferromagnetic topological solitons in thin films** — •Samir Lounis

MA 26.1	Wed	15:00–15:30	H 1058	**Enhanced Nernst effect in van der Waals tellurides** — M. Behnami, M. Gillig, S. Aswartham, G. Shipunov, D. Efremov, B. R. Piening, I. V. Morozov, K. Ochkan, J. Dufouleur, V. Kocsis, C. Hess, M. Putti, F. Caglieris, B. Büchner, •H. Reichlova
MA 26.2	Wed	15:30–16:00	H 1058	**Hybrid transverse magneto-thermoelectric cooling in artificially tilted multilayers** — •Ken-ichi Uchida
MA 26.3	Wed	16:00–16:30	H 1058	**Nonlocal heat engines with hybrid quantum dot systems** — •Rafael Sánchez, Mojtaba S. Tabatabaei, David Sánchez, Alfredo Levy Yeyati
MA 26.4	Wed	16:45–17:15	H 1058	**Large anomalous Nernst thermoelectric performance in $YbMnBi_2$** — •Yu Pan, Congcong Le, Bin He, Sarah Watzman, Mengyu Yao, Johannes Gooth, Joseph Heremans, Yan Sun, Claudia Felser
MA 26.5	Wed	17:15–17:45	H 1058	**A path to suistainable and scalable production of high-performance thermoelectric materials** — •Maria Ibáñez
MA 30.1	Wed	15:00–15:30	EB 301	**Discovery of Hopfion rings in a cubic chiral magnet** — •Nikolai Kiselev
MA 34.1	Thu	9:30–10:00	H 1058	**Giant effective magnetic fields from chiral phonons** — •Dominik M. Juraschek
MA 34.2	Thu	10:00–10:30	H 1058	**Chiral phonons in quantum materials revealed by the thermal Hall effect** — •Gael Grissonnanche
MA 34.3	Thu	10:30–11:00	H 1058	**Phonon chirality and thermal Hall transport** — •Benedetta Flebus, Allan H. MacDonald
MA 34.4	Thu	11:15–11:45	H 1058	**Orbital magnetic moment of phonons in diamagnetic and paraelectric perovskites** — Filip Kadlek, Christelle Kadlek, •Martina Basini, Sergey Kovalev, Jan-Christoph Deinert, Stefano Bonetti, Stanislav Kamba
MA 34.5	Thu	11:45–12:15	H 1058	**Spin-lattice coupling in multiscale modeling** — •Markus Weissenhofer, Sergiy Mankovsky, Svitlana Polesya, Hannah Lange, Akashdeep Kamra, Hubert Ebert, Ulrich Nowak
MA 44.1	Thu	15:00–15:30	EB 301	**Synthetic antiferromagnets with ferromagnetic domains separated by antiferromagnetic domain walls** — •Ruslan Salikov, Fabian Samad, Sebastian Schneider, Darius Pohl, Bernd Rellinghaus, Jürgen Lindner, Nikolai Kiselev, Olav Hellwig
MA 51.1	Fri	9:30–10:00	H 2013	**Functional and microstructural design of multicaloric Heusler alloys** — •Franziska Scheibel, Lukas Pfeuffer, Andreas Taubel, Christian Lauhoff, Philipp Krooss, Thomas Niendorf, Oliver Gutfleisch

Invited Talks of the joint Symposium Three-Dimensional Nanostructures: From Magnetism to Superconductivity (SYMS)

See SYMS for the full program of the symposium.

SYMS 1.1	Mon	9:30–10:00	H 0105	**3D Racetrack Memory** — •Stuart Parkin
SYMS 1.2	Mon	10:00–10:30	H 0105	**Curved electronics: geometry-induced effects at the nanoscale** — •Paola Gentile
SYMS 1.3	Mon	10:30–11:00	H 0105	**Curvilinear micromagnetism** — •Denys Makarov
SYMS 1.4	Mon	11:15–11:45	H 0105	**Study of 3D superconducting nanoarchitectures** — •Rosa Córdoba
SYMS 1.5	Mon	11:45–12:15	H 0105	**3D nanoarchitectures for superconductivity and magnonics** — •Oleksandr Dobrovolskiy

Invited Talks of the joint Symposium SKM Dissertation Prize 2024 (SYSD)

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	9:30–10:00	H 1012	**Nonequilibrium dynamics in constrained quantum many-body systems** — •Johannes Feldmeier
SYSD 1.2	Mon	10:00–10:30	H 1012	**Controlled Manipulation of Magnetic Skyrmions: Generation, Motion and Dynamics** — •Lisa-Marie Kern
SYSD 1.3	Mon	10:30–11:00	H 1012	**Interactions within and between cytoskeletal filaments** — •Charlotta Lorenz

SYSD 1.4	Mon	11:00–11:30	H 1012	**Field theories in nonequilibrium statistical mechanics: from molecules to galaxies** — •Michael te Vrugt
SYSD 1.5	Mon	11:30–12:00	H 1012	**Lightwave control of electrons in graphene** — •Tobias Weitz

Invited Talks of the joint Symposium Synergistic Imaging Techniques: From Spins and Atoms to Ferroic Domains (SYSA)

See SYSA for the full program of the symposium.

SYSA 1.1	Mon	15:00–15:30	H 0105	**Imaging with coherent soft X-rays** — •Bastian Pfau
SYSA 1.2	Mon	15:30–16:00	H 0105	**Exploring ferroelectric domains and domain wall dynamics with quantitative STEM** — •Marta D. Rossell
SYSA 1.3	Mon	16:00–16:30	H 0105	**Scanning Oscillator Piezoresponse Microscopy: new tools to explore domain wall dynamics** — •Neus Domingo, Shiva Raghuraman, Ralph Bulanadi, Patrycja Paruch, Stephen Jesse
SYSA 1.4	Mon	16:45–17:15	H 0105	**Imaging probe nuclei environments using perturbed angular correlation spectroscopy: Examples from multiferroic $BiFeO_3$** — •Doru C. Lupascu, Thien Thanh Dang, Georg Marschick, Marianela Escobar, Astita Dubey, Ian Yap Chang Jie, Juliana Heiniger-Schell
SYSA 1.5	Mon	17:15–17:45	H 0105	**Exploring antiferromagnetic order at the nanoscale with a single spin microscope** — •Vincent Jacques, Aurore Finco

Invited Talks of the joint Symposium Diversity and Equality in Physics (SYDE)

See SYDE for the full program of the symposium.

SYDE 1.1	Tue	9:30–10:00	PTB HS HvHB	**Workplace cultures in physics as a game changer for equal opportunities** — •Martina Erlemann
SYDE 1.2	Tue	10:00–10:30	PTB HS HvHB	**Science on the Web: How networks bias academic communication online** — •Agnes Horvat
SYDE 1.3	Tue	10:30–11:00	PTB HS HvHB	**Citation inequity and gendered citation practices in contemporary physics** — •Erin Teich, Jason Kim, Christopher Lynn, Samantha Simon, Andrei Klishin, Karol Szymula, Pragya Srivastava, Lee Bassett, Perry Zurn, Jordan Dworkin, Dani Bassett
SYDE 1.4	Tue	11:15–11:45	PTB HS HvHB	**The Diversity-Innovation Paradox in Science** — •Bas Hofstra
SYDE 1.5	Tue	11:45–12:15	PTB HS HvHB	**Gender and retention patterns among U.S. faculty** — •Aaron Clauset

Invited Talks of the joint Symposium Emerging Materials for Renewable Energy Conversion (SYEM)

See SYEM for the full program of the symposium.

SYEM 1.1	Wed	9:30–10:00	H 0105	**Non-critical Materials Production for a Green Energy Transition** — •Anke Weidenkaff, Wenjie Xie, Marc Wiedenmeyer
SYEM 1.2	Wed	10:00–10:30	H 0105	**Strategies for the morphological design of photoactive oxynitride particles and electrodes for solar water-splitting.** — •Simone Pokrant
SYEM 1.3	Wed	10:30–11:00	H 0105	**Computational workflows for an accelerated design of novel materials and interfaces** — •Ivano Eligio Castelli
SYEM 1.4	Wed	11:30–11:45	H 0105	**Autonomous composition control of emerging nitride materials for solar energy conversion** — •Andriy Zakutayev
SYEM 1.5	Wed	11:45–12:00	H 0105	**Understanding and tailoring the catalytic activity of spinel and perovskite surfaces from first principles calculations** — •Rossitza Pentcheva
SYEM 1.6	Wed	12:00–12:15	H 0105	**Mastering Compositional Complexity in High Entropy Materials for Energy Applications - Towards Accelerated Materials Discovery by Integration of High-throughput Experimentation, Simulation, and Materials Informatics** — •Alfred Ludwig

Sessions

MA 1.1–1.3	Sun	16:00–18:10	H 1058	**Tutorial: Thermoelectricity – Fundamental Aspects, Materials, Applications (joint session TT/TUT/MA)**
MA 2.1–2.12	Mon	9:30–12:45	H 1058	**Computational Magnetism I**
MA 3.1–3.11	Mon	9:30–12:45	H 2013	**Ultrafast Magnetization Effects I**
MA 4.1–4.11	Mon	9:30–12:30	EB 107	**Magnetic Heusler Compounds and Complex Magnetic Oxides**
MA 5.1–5.12	Mon	9:30–12:45	EB 202	**Spin Structures and Magnetic Phase Transitions I**
MA 6.1–6.12	Mon	9:30–13:00	EB 301	**Molecular Magnetism**
MA 7.1–7.12	Mon	9:30–12:45	EB 407	**Bulk Magnetic Materials and Magnetic Particles/Clusters**
MA 8.1–8.7	Mon	15:00–18:25	H 1058	**INNOMAG e.V. Prizes 2024 (Diplom-/Master and Ph.D. Thesis)**
MA 9.1–9.12	Mon	15:00–18:30	H 2013	**Ultrafast Magnetization Effects II**
MA 10.1–10.11	Mon	15:00–18:00	EB 107	**Electron Theory of Magnetism and Correlations/Other Theory**
MA 11.1–11.14	Mon	15:00–18:45	EB 202	**Functional Antiferromagnetism**
MA 12.1–12.13	Mon	15:00–18:30	EB 301	**Skyrmions I**
MA 13.1–13.8	Mon	15:00–17:00	EB 407	**Micro- and Nanostructured Magnetic Materials**
MA 14.1–14.9	Tue	9:30–13:15	H 1058	**Focus Session: Frustrated Magnetism and Local Order (joint session MA/TT)**
MA 15.1–15.13	Tue	9:30–13:00	H 2013	**Topological Insulators and Weyl Semimetals (joint session MA/TT)**
MA 16.1–16.11	Tue	9:30–12:30	EB 107	**Magnonics I**
MA 17.1–17.12	Tue	9:30–12:45	EB 202	**Computational Magnetism II**
MA 18.1–18.13	Tue	9:30–13:00	EB 301	**Magnetic Imaging and Sensors I**
MA 19.1–19.11	Tue	9:30–12:30	EB 407	**Surface Magnetism**
MA 20.1–20.46	Tue	16:30–19:00	Poster A	**Poster I**
MA 21.1–21.10	Wed	9:30–13:15	H 1058	**Phd Focus Session: Altermagnets: Foundations and Experimental Evidence**
MA 22.1–22.9	Wed	9:30–12:15	H 2013	**Thin Films: Coupling Effects and Exchange Bias**
MA 23.1–23.6	Wed	9:30–11:00	EB 107	**Magnonics II**
MA 24.1–24.14	Wed	9:30–13:15	EB 202	**Terahertz Spintronics I**
MA 25.1–25.13	Wed	9:30–13:00	EB 301	**Magnetic Imaging and Sensors II**
MA 26.1–26.5	Wed	15:00–17:45	H 1058	**Focus Session: Unconventional Thermoelectric Phenomena and Materials (joint session MA/TT)**
MA 27.1–27.13	Wed	15:00–18:30	H 2013	**Frustrated Magnets I**
MA 28.1–28.8	Wed	15:00–17:00	EB 107	**Thin Films: Magnetic Anisotropy**
MA 29.1–29.15	Wed	15:00–19:00	EB 202	**Spin-Dependent Phenomena in 2 D**
MA 30.1–30.12	Wed	15:00–18:30	EB 301	**Skyrmions II**
MA 31.1–31.11	Wed	15:00–18:00	EB 407	**Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)**
MA 32.1–32.7	Wed	15:00–18:00	Poster E	**$SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor: Poster (joint session TT/KFM/MA/O)**
MA 33.1–33.7	Thu	9:30–12:45	H 0104	**Focus Session: $SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor I (joint session TT/KFM/MA/O)**
MA 34.1–34.5	Thu	9:30–12:15	H 1058	**Focus Session: Emerging Magnetic Phenomena from Chiral Phonons I (joint session MA/TT)**
MA 35.1–35.12	Thu	9:30–12:45	H 2013	**Spin Transport and Orbitronics, Spin-Hall Effects I (joint session MA/TT)**
MA 36.1–36.5	Thu	9:30–10:45	EB 202	**Terahertz Spintronics II**
MA 37.1–37.13	Thu	9:30–13:00	EB 301	**Skyrmions III**
MA 38.1–38.6	Thu	11:15–12:45	EB 202	**Ultrafast Magnetization Effects III**
MA 39.1–39.11	Thu	15:00–18:00	H 0104	**$SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor II (joint session TT/KFM/MA/O)**
MA 40.1–40.10	Thu	15:00–17:45	H 1058	**Frustrated Magnets II**
MA 41.1–41.10	Thu	15:00–17:45	H 2013	**Spintronics (Other Effects)**
MA 42.1–42.4	Thu	15:00–16:00	EB 107	**Spin Transport and Orbitronics, Spin-Hall Effects II (joint session MA/TT)**
MA 43.1–43.8	Thu	15:00–17:15	EB 202	**Magnetic Semiconductors, Magnetization Dynamics and Damping**

MA 44.1–44.9	Thu	15:00–17:45	EB 301	**Non-Skyrmionic Magnetic Textures**
MA 45.1–45.4	Thu	15:00–16:00	EB 407	**Spin Structures and Magnetic Phase Transitions II**
MA 46.1–46.86	Thu	15:00–18:00	Poster C	**Poster II**
MA 47.1–47.33	Thu	15:00–18:00	Poster D	**Poster III**
MA 48	Thu	18:00–19:00	H 1058	**Members' Assembly**
MA 49.1–49.11	Fri	9:30–12:30	H 0104	**$SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor III (joint session TT/KFM/MA/O)**
MA 50.1–50.8	Fri	9:30–11:30	H 1058	**Focus Session: Emerging Magnetic Phenomena from Chiral Phonons II (joint session MA/TT)**
MA 51.1–51.13	Fri	9:30–13:15	H 2013	**Caloric Effects in Ferromagnetic Materials**
MA 52.1–52.15	Fri	9:30–13:30	EB 202	**Altermagnets**
MA 53.1–53.5	Fri	9:30–10:45	EB 301	**Skyrmions IV**

Members' Assembly of the Magnetism Division

Thursday 18:00–19:00 H 1058

- Bericht
- Wahl
- Verschiedenes

MA 1: Tutorial: Thermoelectricity – Fundamental Aspects, Materials, Applications (joint session TT/TUT/MA)

Thermoelectric effects have been discussed for several decades and have found widespread applications. Characteristic physical quantities are the efficiency, the figure of merit, ZT, and the power factor. In particular, increasing ZT has been the issue for many years. In recent developments, the focus has been on "unconventional" thermoelectric phenomena and materials: these include, in particular, transverse thermoelectric effects where the generated charge current is perpendicular to the temperature gradient, as can be observed, e.g., when applying a magnetic field (ordinary and anomalous Nernst effect). Transverse thermoelectricity can be found even without a magnetic field, e.g., in goniopolar materials (which have n- and p-type parts of the Fermi surface at the same time). – The Tutorial, jointly organized by the divisions MA and TT, will cover the basic physics of thermoelectricity, as well as discuss the question which materials are most useful for which applications, respectively. Attending the Tutorial thus will allow the non-experts in the field to fully appreciate the related presentations in the conference.

Organizers: Ulrich Eckern (University of Augsburg), Claudia Felser (MPI CPS Dresden), Anke Weidenkaff (TU Darmstadt & Fraunhofer IWKS)

Time: Sunday 16:00–18:10 Location: H 1058

Tutorial MA 1.1 Sun 16:00 H 1058

Transport properties of thermoelectric materials — •Maria Ibáñez — Institute of Science and Technology (ISTA), Klosterneuburg, Austria

Thermoelectricity is the phenomenon of converting heat directly into electricity and vice versa. As energy harvesters, thermoelectric devices can be used to partially recover large quantities of the waste heat to reduce our primary energy production or to run low-power devices, especially those that require autonomy, such as sensors and transmitters in remote or difficult-to-access locations. Furthermore, its reversible nature allows thermoelectric devices to be operated as precise coolers for small-scale temperature control. Such localized cooling is crucial in infrared detectors, microelectronics, and optoelectronics, among others, where space is limited, and heat dissipation is localized. This lecture will provide a comprehensive introduction to thermoelectricity. We will begin by giving a brief history of thermoelectrics, a description of the phenomenon, and its potential applications. Later on, we will introduce the fundamental principles of thermoelectricity, emphasizing the importance of material properties, in particular, those related to electronic and thermal transport. We will present the thermoelectric figure of merit and its significance as a metric for evaluating thermoelectric efficiency. ZT components, including electrical conductivity, Seebeck coefficient, and thermal conductivity, and their interplay in determining the overall performance will be deeply evaluated, and the different strategies to maximize performance will be presented using, as examples, traditional thermoelectric materials.

5 min. break

Tutorial MA 1.2 Sun 16:45 H 1058

Thermoelectricity: basic concepts, and applications to nanoscale heat engines — •Karol I. Wysokiński — Institute of Physics, M. Curie-Sklodowska University, Lublin, Poland

Thermoelectric power generators directly convert heat into electricity. These solid-state heat engines have no moving parts and are extremely reliable. Their performance is characterized by efficiency and power output, both of which depend on a single parameter called the thermoelectric figure of merit ZT, of which they are monotonically increasing functions. The dimensionless parameter ZT depends on the materials' transport coefficients: conductivity, thermal conductivity, Seebeck coefficient, and operating temperature. However, due to the coupling between conductivity and thermal conductivity quantified by the Wiedemann-Franz ratio obeyed by standard materials, the quest to increase ZT is a challenge for contemporary materials physics. Novel materials and structures have been proposed to overcome these difficulties on the way to achieve efficient waste heat harvesters with possible applications at large and small scales.

During the lecture, the above main ideas in the theory of thermoelectricity will be discussed, and their application in the nanoscale illustrated by the analysis of the devices consisting of a single or two quantum dots, tunnel coupled to two or more external electrodes. The electrodes may be simple metals, ferromagnets, or superconductors. The steady-state transport characteristics of the devices will be analysed. Special attention will be paid to the role of interactions between the carriers, and the non-linear effects prevalent in such structures.

5 min. break

Tutorial MA 1.3 Sun 17:30 H 1058

Novel thermoelectric materials: synthesis, characterization and application — •Wenjie Xie — Institute of Materials Science, Technical University of Darmstadt, Darmstadt, Germany — Fraunhofer IWKS, Alzenau, Germany

Thermoelectricity offers a direct and highly efficient approach for converting heat into electricity, relying on two key factors: Carnot efficiency and the materials-dependent property, ZT. Over the past two decades, significant progress has been made in pursuing high ZT thermoelectric materials, culminating in a bulk ZT surpassing 3. In this presentation, we offer a comprehensive review of the development of novel thermoelectric materials, categorized according to their application temperature ranges: low/room, medium, and high temperatures.

Within each temperature range, we will focus on the synthesis and characterization of one or two exemplary materials. For instance, the discussion will delve into materials such as Bi_2Te_3 for room temperature applications, SnSe/PbTe for medium temperature regimes, and the utilization of half-Heusler and oxide materials for high-temperature scenarios. Furthermore, the sustainable aspects of thermoelectric material synthesis will be explored.

Last, we will discuss the practical application of thermoelectric materials, examining their usage in real-world scenarios. The discussion will mainly focus on Bi_2Te_3, half-Heusler, and oxides, providing a comprehensive overview of the current landscape and future potential in the realm of thermoelectric cooling and power generation.

MA 2: Computational Magnetism I

Time: Monday 9:30–12:45 Location: H 1058

MA 2.1 Mon 9:30 H 1058

Inertial spin waves in non-collinear spin structures — Mikhail Cherkasskii[1], Ritwik Mondal[2], and •Levente Rózsa[3,4] — [1]RWTH Aachen, Aachen, Germany — [2]Indian Institute of Technology (ISM) Dhanbad, Dhanbad, India — [3]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [4]Budapest University of Technology and Economics, Budapest, Hungary

Inertial phenomena emerge in magnetic materials at very short time scales, where the directions of the angular momentum and the magnetic moment become separated. The inertia gives rise to high-frequency excitations which have been observed in ferromagnetic resonance experiments [1]. These excitations form inertial spin-wave bands which have been studied in ferromagnets and collinear antiferromagnets [2].

Here, we discuss the properties of inertial spin waves in non-collinear spin structures. We generalize the linearized inertial Landau-Lifshitz-Gilbert equation used for the calculation of spin-wave modes to arbitrary spin configurations. We apply the method to spin spirals to interpolate between the ferromagnetic and collinear antiferromagnetic limits, and demonstrate the formation of flat bands and non-reciprocal inertial spin-wave dispersion.

[1] K. Neeraj et al., Nat. Phys. 17, 245 (2021). [2] R. Mondal et al., J. Magn. Magn. Mater. 579, 170830 (2023).

MA 2.2 Mon 9:45 H 1058

Atomistic spin dynamics investigation of laser-induced ultrafast magnetization switching in layered ferrimagnets — •José Miguel Lendínez, Silvia Gallego, and Unai Atxitia — Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, 28049 Madrid, Spain

The experimental demonstration of field-free magnetization switching in GdFeCo alloys opened the door to a promising route toward faster and more energy efficient data storage. A recent semi-phenomenological theory has proposed that a fast, laser-induced demagnetization below a threshold value is necessary for switching [1]. Notably, this threshold scales inversely proportional to the number of exchange-coupled nearest neighbours considered in the generic model, which in the simplest case is directly linked to the underlying lattice structure [2].

In this work we use atomistic spin dynamics simulations to investigate the possibility energy efficient laser-induced magnetization switching in generic layered ferrimagnetic alloys. Importantly, the interlayer exchange coupling tunes the dimension of the underlying magnetic model, from bulk 3D alloy for finite values to a 2D alloy for vanishing values. We demonstrate that the larger fluctuations in the 2D system are beneficial for a lower energy switching in comparison to the 3D systems.

[1] F. Jakobs and U. Atxitia, Phys. Rev. Lett. **129** 037203 (2022).
[2] J. A. Velez, R. M. Otxoa, and U. Atxitia, Appl. Phys. Lett. **123**, 112402 (2023).

MA 2.3 Mon 10:00 H 1058

T-symmetric second order optical responses in noncollinear AFMs — •Javier Sivianes[1], Flaviano José Dos Santos[2], and Julen Ibañez-Azpiroz[1,3,4] — [1]Centro de Física de Materiales, UPV, Donostia — [2]Theory and Simulation of Materials (THEOS), and National Centre for Computational Design and Discovery of Novel Materials (MARVEL) — [3]Ikerbasque Foundation, Bilbao, Spain — [4]Donostia International Physics Center (DIPC), Donostia, Spain

There is a growing interest in Mn_5Si_3, a compound that exhibits altermagnet and noncollinear AFM phases [1]. The latter presents a peculiar feature; its atomic positions belong to the centrosymmetric $6/mmm$ point group while its magnetic point group $11'$ lacks inversion symmetry. Notably, this allows for finite second order optical responses to take place such as the shift and injection currents or the nonlinear Hall effect.

In this work we report DFT calculations on the quadratic optical properties of noncollinear Mn_5Si_3, which reach a substantial magnitude comparable to ferroelectric materials. In order to gain insight into the role of the magnetic structure in the nonlinear charge flow, we build a double-exchange tight-binding model. The nonlinear optical signature could be employed to distinguish among the various suggested magnetic structures of the material [1].

[1] N. Biniskos. et al., Phys. Rev. B **105**, 104404 (2022).

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MA 2.4 Mon 10:15 H 1058

Spin wave transport in ferromagnetic and antiferromagnetic bilayers — •Moumita Kundu[1], Levente Rozsa[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, Konstanz, Germany — [2]Wigner Research Center for Physics, Budapest, Hungary

Spin transport in magnetic insulators is crucial for spin-based multi-functional devices. In our work, we study the transport of spin waves in ferromagnetic(FM) and antiferromagnetic(AFM) insulator bilayers. We focus on uncompensated interfaces that can essentially change the ordering temperatures for both the FM and the AFM[1].

For our investigation, we use atomistic spin dynamic simulations, where magnetic interactions are described using an extended Heisenberg model and we use the stochastic Landau-Lifshitz-Gilbert equation as the equation of motion. It is seen that with both, thermal and monochromatic excitations, the spin wave decays exponentially having a propagation length of several nanometers. The transport of magnons is studied via the magnon accumulation which is defined as the difference in the magnon population leading to diffusion. Additionally, the dispersion relation of such magnons are also calculated for different temperatures. We study the dependence of the propagation of magnons in such heterostructures on damping, anisotropy and exchange coupling at the interface.

[1] V. Brehm, M. Evers, U. Ritzmann, and U. Nowak, PHYSICAL REVIEW B **105**, 104408(2022)

MA 2.5 Mon 10:30 H 1058

Current-induced spin polarization in chiral Tellurium: a first-principles quantum transport study — •Reena Gupta and Andrea Droghetti — School of Physics and CRANN, Trinity College, 2, Dublin, Ireland

Te is a naturally p-doped semiconductor with a chiral structure, where an electrical current causes the conduction electrons to become spin polarized parallel to the transport direction. Here we present a comprehensive theoretical study of this effect by employing density functional theory (DFT) combined with the non-equilibrium Green's functions (NEGF) technique for quantum transport. We suggest that the spin polarization can quantitatively be estimated in terms of two complementary quantities, namely the non-equilibrium magnetic moments and the spin current density. The calculated magnetic moments are directly compared with the values from previous the- oretical studies obtaining overall consistent results. On the other hand, the inspection of the spin current density provides insights of the magnetotransport properties of the material. Specifically, we predict that the resistance along a Te wire changes when an external magnetic field is applied parallel or antiparallel to the charge current direction. The computed magnetoresistance is however quite small. Finally, we show that the description of the current-induced spin polarization in terms of the spin current establishes a straightforward connection with the phenomenon called chiral-induced spin selectivity, recently observed in several nano-junctions.

MA 2.6 Mon 10:45 H 1058

Magnetoelastic effects on sound velocity — Pablo Nieves[1,2], Julian Tranchida[3], Svetoslav Nikolov[4], Alberto Fraile[5], and •Dominik Legut[1] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czechia — [2]University of Oviedo, Oviedo, Spain — [3]CEA, DES/IRESNE/DEC, France — [4]Sandia National Laboratories, Alberque, NM, USA — [5]Bangor University, Bangor, Wales, UK

In this work, we leverage atomistic spin-lattice simulations to examine how magnetic interactions impact the propagation of sound waves through a ferromagnetic material. To achieve this, we characterize the sound wave velocity in BCC iron, a prototypical ferromagnetic material, using three different approaches that are based on the oscillations of kinetic energy, finite-displacement derived forces, and corrections to the elastic constants, respectively. Successfully applying these methods within the spin-lattice framework, we find good agreement with the Simon effect including high-order terms. In analogy to experiments, morphic coefficients associated with the transverse and longitudinal waves propagating along the [001] direction are extracted from fits to the fractional change in sound velocity data. The present efforts represent an advancement in magnetoelastic modeling capabilities which can promote the design of future magnetoacoustic devices [1].

1. P. Nieves, J. Tranchida, S. Nikolov, A. Fraile, and D. Legut, Phys. Rev. B 105, 134430 (2022).

15 min. break

MA 2.7 Mon 11:15 H 1058

Are Magnons Just The Van Der Waals Interaction In Disguise? — •Robert Lawrence — School of Physics, Engineering and Technology, University of York, Heslington, North Yorks. YO10 5DD, UK

For systems without significant magnetism (such as non-magnetic, carbon-based molecules) it is well-known that correctly capturing the properties of the system – such as the interlayer spacing of graphite – requires considering the dynamical correlations, such as the van der Waals interactions. These dynamical correlations lead to quantised electric dipole waves throughout the system [1]. In magnetic systems magnetic correlations are also possible, in addition to the electric dipole-induced electric dipole interactions.

In this talk, we present our work extending semi-empirical van der Waals models to include both the magnetic and electric parts simultaneously, and demonstrate how this can naturally lead to the emergence of the Heisenberg model of magnetism. Finally, we discuss how this model leads to the ability to predict long-range magnetic coupling (and hence parameterise magnons) in a more computationally efficient manner than finite displacements on large supercells.

[1] A. Ambrosetti, N. Ferri, R.A. Distasio Jr. , A. Tkatchenko, Wavelike charge density fluctuations and van der Waals interactions at the nanoscale, *Science*, 351, 6278, 2016

MA 2.8 Mon 11:30 H 1058

Unravelling local spin-model parameters based on noncollinear magnetic states — Bendegúz Nyári[1,2] and •László Szunyogh[2,1] — [1]HUN-REN-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budapest Hungary — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary

The theory of local spin-interactions as calculated from non-collinear magnetic states via multiple scattering Green's function technique will be described. Two alternative formalisms is implemented to perform calculations for specific spin-configurations of a Cr trimer deposited on a Au(111) surface. The two calculations provide with the same two-spin rotation energies, however, the local interaction parameters turn out to be remarkably different. The ambiguity between these results occurs due to longitudinal contributions to the interactions and can perfectly be eliminated in terms of projections to the transversal subspace in the local coordinate system. Moreover, a global spin model containing isotropic two-spin and four-spin interactions is used to calculate the two-spin rotation energies and a reasonable agreement is found between the results obtained from the global and local models. An analytic formulation based on a Green's function expansion technique also clearly identifies the higher-order global multispin interactions as the source of the tensorial local spin-model parameters as suggested earlier [1,2].

[1] M. dos Santos Dias et al., Phys. Rev. B 103, L140408 (2021).
[2] M. dos Santos Dias et al., Phys. Rev. B 105, 026402 (2022).

MA 2.9 Mon 11:45 H 1058

Bi-directionally coupled simulation of magnetization dynamics and elastodynamics — •Peter Flauger[1], Matthias Küss[2], Michael Karl Steinbauer[1], Bernhard Emhofer[1], Matthias Volz[3], Hubert Krenner[3], Manfred Albrecht[2], and Claas Abert[1] — [1]University of Vienna — [2]University of Augsburg — [3]University of Münster

The interaction of surface acoustic waves (SAWs) with spin waves (SWs) in magnetic thin films via the magnetoelastic effect allows e.g. for the excitation of SW modes with prolonged propagation distances [1] or magnetic field sensors [2] and is thus of current scientific interest. In this work, we present a self-consistent solver for coupled magnetization dynamics and linear elasticity simulations based on the finite-differences method as an extension to the python library magnum.np [3]. This solver is then used to investigate the excitation of spin waves in magnetic thin films by SAWs. The observed non-reciprocity of the excitation with respect to the propagation direction and the power loss of the SAW are compared to experimental results on Ni films on a $LiTaO_3$ substrate [4].

[1] C. Chen *et al.*, Appl. Phys. Lett. **110**, 072401 (2017).
[2] A. Kittmann *et al.*, Sci. Rep. **8**, 278 (2018).
[3] F. Bruckner *et al.*, Sci Rep. **13**, 12054 (2023).
[4] M. Küß *et al.*, Phys. Rev. Appl. **15**, 034046 (2021).

MA 2.10 Mon 12:00 H 1058

Relativistic magnetic interactions from non-orthogonal basis sets — •Gabriel Martínez-Carracedo[1], László Oroszlány[2], Amador García-Fuente[1], László Szunyogh[3], Ferrer Jaime[1], László Udvardi[3], and Bendegúz Nyári[3] — [1]Departamento de Física, Universidad de Oviedo, 33007 Oviedo, Spain — [2]Department of Physics of Complex Systems, Eötvös Loránd University, 1117 Budapest, Hungary — [3]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics, Mûegyetem rkp. 3., H-1111 Budapest, Hungary

We introduce a method using density functional theory to determine magnetic exchange interactions and on-site anisotropy tensors in extended Heisenberg spin models. Our approach, based on the Liechtenstein-Katsnelson-Antropov-Gubanov torque formalism, involves energy variations during infinitesimal rotations. Using a non-orthogonal basis set of pseudo-atomic orbitals in the Kohn-Sham Hamiltonian expansion, we demonstrate the method's accuracy and flexibility by computing tensors for magnetic nanostructures and two-dimensional magnets and results align well with the Korringa-Kohn-Rostoker Green's function method.

MA 2.11 Mon 12:15 H 1058

Quantum effects on unconventional pinch-point singularities in pyrochlore materials — •Lasse Gresista[1,2], Simon Trebst[1], and Yasir Iqbal[2] — [1]Institute for Theoretical Physics, University of Cologne, Germany — [2]Department of Physics and Quantum Centre of Excellence for Diamond and Emergent Materials (QuCenDiEM), Indian Institute of Technology Madras, India

The discovery of emergent gauge theories in condensed matter systems is associated with novel phenomena such as fractionalization and topological excitations. A prime example are spin ice compounds, which are materials hosting a ground state described by an emergent U(1) gauge theory, featuring monopole excitations arising from the fractionalization of microscopic spin degrees of freedom. Remarkably, signatures of the gauge structure are visible in neutron scattering measurements as *pinch-point* singularities. Recently, classical spin liquids on the pyrochlore lattice have been proposed with a higher-rank gauge structure, where instead of a conventional gauge field the low-energy physics is described by fluctuations of a tensor field with a continuous gauge freedom. The corresponding classical correlations show variations of the conventional pinch-point singularities, such as *pinch-lines* or *multi-fold* pinch-points. Here, we investigate the effect of quantum fluctuations on these signatures using a pseudo-fermion functional renormalization group approach. We observe a significant modification of the signal drastically different from the simple broadening due to thermal fluctuations, highliting the importantance of quantum fluctuations in possible material realizations and interpretation of experimental observations.

MA 2.12 Mon 12:30 H 1058

Magnetodynamics in molecular dynamics simulations using the thermal Stoner-Wohlfarth model — •Deniz Mostarac, Andrey Kuznetzov, Pedro A. Sanchez, Dieter Süss, and Sofia Kantorovich — University of Vienna, Vienna, Austria

In this contribution we present a state-of-the-art, hybrid approach, based on an extension of the generalized Stoner-Wohlfarth model to capture thermal activation in magnetic colloids. With this approach we can simulate internal magnetization dynamics of magnetic colloids, including both Brownian and Néel relaxation mechanisms, in large scale, long time scale bulk simulations. The model is qualified against classical systems (solid superparamagnet and a dilute ferrofluid) that are well understood theoretically to demonstrate the range of applicability and the scaleability of the model. Finally, a case study of a suspension of magnetic filaments with superparamagnetic colloids is presented, that highlights that long-range dipolar interactions in quasi-infinite colloidal systems, particularly ones where the translational and rotational degrees of freedom between the colloids are coupled,[1,2] necessitates the use of a sophisticated model incorporating magnetodynamics explicitly and accurately. [1] Mostarac, D., et al. Nanoscale (2020). [2] Mostarac, D., et al. Macromolecules (2022).

MA 3: Ultrafast Magnetization Effects I

Time: Monday 9:30–12:45 Location: H 2013

Invited Talk MA 3.1 Mon 9:30 H 2013

Effects of Magnetization Inertia in Spin Dynamics — •Anna Semisalova — Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany

Magnetization inertia has been shown to give rise to an additional motion of magnetization - a THz-frequency nutation, superimposed on the regular GHz precession [1-4], attractive for ultrafast magnonics [5]. Furthermore, in nanoparticles, magnetic nutation can be induced by a non-uniform spin configuration due to surface anisotropy [6]. In this talk, I discuss how to resolve effects of inertia on spin dynamics in anisotropic ferromagnets [7]. Within the inertial LLG equation, we find a reduction of the ferromagnetic resonance (FMR) frequency for both aligned and non-aligned modes due to inertia. We illustrate this phenomenon for model thin film systems with cubic and uniaxial magnetocrystalline anisotropy. Notably, for an out-of-plane magnetic field the FMR frequency dependence of a thin film becomes non-linear, in contrast to conventionally used Kittel formula. We also find that the nutation frequency increases with the magnetic anisotropy and the applied field. These higher-order corrections due to inertia are important for an accurate evaluation of magnetic anisotropy and g-factor, and for an interpretation of spin dynamics experiments at higher frequencies [7]. Support from DFG is gratefully acknowledged (SE 2853/1-1 | AL 618/37-1; CRC/TRR 270). [1] PRB 83, 020410(R) (2011); [2] PRB 102, 184432 (2020); [3] Nat. Phys. 17, 245 (2021); [4] JMMM 579, 170830 (2023); [5] PRB 103, 174435 (2021); [6] PRB 98, 165444 (2018); [7] PRB 106, 054428 (2022)

MA 3.2 Mon 10:00 H 2013

Ultrafast generation of nonthermal magnons in iron: *Ab initio* parameterized calculations — •Markus Weissenhofer[1,2] and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Freie Universität Berlin, Berlin, Germany

Ultrafast laser excitation of ferromagnetic metals gives rise to correlated, highly non-equilibrium dynamics of electrons, spins and lattice, which are, however, poorly described by the widely used three-temperature model (3TM). We develop a fully *ab initio* parameterized out-of-equilibrium theory based on a quantum kinetic approach – termed *(N+2) temperature model* – that describes magnon occupation dynamics due to electron-magnon scattering [1]. We apply this model to perform quantitative simulations on the ultrafast, laser-induced generation of magnons in iron and demonstrate that on these timescales the magnon distribution is non-thermal: predominantly high-energy magnons are created, while the magnon occupation close to the center of the Brillouin zone even decreases, due to a repopulation towards higher energy states. We show that the 3TM can be derived from our model and compare it with our microscopic calculations. In doing so, we demonstrate that the simple relation between magnetization and temperature computed at equilibrium does not hold in the ultrafast regime and that the 3TM greatly overestimates the demagnetization. Our calculations show that ultrafast generation of non-thermal magnons provides a sizable demagnetization within 200 fs and, thus, emphasize the importance of magnons for ultrafast demagnetization. [1] M.Weißenhofer and P.M. Oppeneer, arXiv:2309.14167

MA 3.3 Mon 10:15 H 2013

Spin nutation driven non-resonantly by ultrashort laser pulses — •A. De[1], J. Schlegel[2], A. Lentfert[1], L. Scheuer[1], B. Stadtmüller[1], P. Pirro[1], G. von Freymann[1,3], U. Nowak[2], and M. Aeschlimann[1] — [1]RPTU Kaiserslautern-Landau — [2]Universität Konstanz — [3]Fraunhofer ITWM, Kaiserslautern

The interaction of ultrashort laser pulses with ferromagnet can trigger a variety of new phenomena such as ultrafast demagnetization, all-optical switching, etc. In this work, we focus on the optically driven magnetization dynamics in the yet unexplored timescale between ultrafast demagnetization and the collective precession motion of the spin system. In this intermediate time window, the direction of the magnetic moment and angular momentum are transiently separated due to inertia. This results in additional oscillations, known as nutation, superimposed on the usual precession, with higher frequencies but smaller amplitudes and relaxation times. We experimentally observe nutation (with frequency around 100 GHz) in permalloy thin films by all-optical time-resolved magneto-optical Kerr effect (TR-MOKE) measurements. The nutation frequency shows a negligible dependence on magnetic field and film thickness. These results are confirmed by atomistic spin model simulations, providing insights into a deeper understanding of nutation at ultrafast timescales.

MA 3.4 Mon 10:30 H 2013

Sub-wavelength localised all-optical helicity-independent switching in GdTbCo using plasmonic gold nanodisks — Themistoklis Sidiropoulos, •Puloma Singh, Tino Noll, Michael Schneider, Dieter Engel, Felix Steinbach, Ingo Will, Denny Sommer, Clemens von Korff Schmising, and Stefan Eisebitt — Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany

All-optical helicity-independent switching (AO-HIS) is of interest for ultrafast and energy efficient magnetic switching in future magnetic data storage approaches. Yet, to achieve high bit density magnetic recording it is necessary to reduce the size of magnetic bits while controlling their shape and position. Metallic nanostructures that support localized surface plasmons enable electromagnetic confinement well below the diffraction limit and rare-earth transition metal alloys such as GdTbCo have demonstrated nanometer-sized stable domains. Here, we deposit plasmonic gold nanodisks on GdTbCo films and probe the magnetic state using magnetic force microscopy. We observe localised AO-HIS of the sample after resonant excitation of the gold nanodisks by a single 370 fs long laser pulse with a center wavelength of 1030 nm. We demonstrate that the strong localization of optical fields through plasmonic nanodisks enables nanoscale AOS-HIS at a sub-wavelength scale length which is comparable to structure sizes in commercial heat assisted magnetic recording. Moreover, we study the influence of the localized electromagnetic field enhancement by the plasmonic nanoparticles on the required fluence to switch the magnetization.

MA 3.5 Mon 10:45 H 2013

Influencing ultrafast demagnetization with the OAM of light — •Paul Herrgen, Eva Prinz, Benjamin Stadtmüller, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

As bosons, photons always have a spin angular momentum, which is associated with left- or right-handed circular polarization. This angular momentum is limited to values of $\pm 1\hbar$. Additionally, the photons can also have an orbital angular momentum (OAM). With an angular momentum of $l\hbar$ with $l \in \mathbb{Z}$ it is possible to increase the total angular momentum of the photons drastically.

In contrast to the spin angular momentum, we found a significant influence of the orbital angular momentum of light on the ultrafast magnetization dynamics. Interestingly, the photonic OAM changes the magnetization only after the interaction of the light pulse with the material [1]. Furthermore, we find a clear relationship between the influence of photonic OAM and the angle between the wave vector of the OAM beam and the magnetization. These empirical results provide the basis for a microscopic model of the OAM-driven magnetization dynamics.

[1]: Prinz et al., arXiv:2206.07502

15 min. break

MA 3.6 Mon 11:15 H 2013

Ultrafast Spin Dynamics in non-collinear Antiferromagnetic Mn_3Sn — •Chongxiao Fan[1,2], Bingke Xiang[3], Dante Kennes[2,1], Angel Rubio[1,4], Yihua Wang[3], and Peizhe Tang[5,1] — [1]Max

Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany. — [2]Institut für Theorie der Statistischen Physik, RWTH Aachen University, 52062 Aachen, Germany. — [3]State Key Laboratory of Surface Physics and Department of Physics, Fudan University, Shanghai 200433, China — [4]Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth avenue, New York NY 10010, USA. — [5]School of Materials Science and Engineering, Beihang University, Beijing 100191, China

Ultrafast manipulation of magnetic moments is a captivating subject within contemporary magnetism and spintronics. In this work, we conduct a pump-probe experiment on the non-collinear antiferromagnet Mn_3Sn, which shows large anomalous Hall effect due to nontrivial topology of its electron band structure. The observed asynchronous alteration after the pump in both the magneto-optical Kerr signal and reflectivity implies changes linked not only to the electron occupation but also to a change of the spin configuration. The relatively low heat capacity of electrons will cause a rapid increase in electron temperature and thermoelectric current can generate polarized current. Spin dynamics calculation confirmed the possible formation of a net magnetization when the pump fluence is large. Our research uncovers novel phenomena within antiferromagnets, offering a fresh approach to comprehend ultrafast physics in magnetic systems.

MA 3.7 Mon 11:30 H 2013

Ab initio investigation of laser-induced ultrafast demagnetization of L10 FePt: Intensity dependence and importance of electron coherence — •Mrudul Muraleedharan S. and Peter M. Oppeneer — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

We theoretically investigate the optically-induced demagnetization of ferromagnetic FePt using the time-dependent density functional theory (TDDFT). We compare the demagnetization mechanism in the perturbative and nonperturbative limits of light-matter interaction and show how the underlying mechanism of the ultrafast demagnetization depends on the driving laser intensity. Our calculations show that the femtosecond demagnetization results from a nonlinear optomagnetic effect akin to the inverse Faraday effect. The demagnetization scales quadratically with the electric field E in the perturbative limit, i.e., $\Delta M_z \propto E^2$. Moreover, the magnetization dynamics happens dominantly at even multiples $n\omega_0$, $(n = 0, 2, \cdots)$ of the pump-laser frequency ω_0. We further investigate the demagnetization in conjunction to the optically-induced change of electron occupations and electron correlations. Comparing the *ab initio* computed demagnetizations with those calculated from spin occupations, we show that electronic coherence plays a dominant role in the demagnetization process, whereas interpretations based on the time-dependent occupation numbers poorly describe the ultrafast demagnetization.

MA 3.8 Mon 11:45 H 2013

Ultrafast dynamics of different magnetic properties in a helical Heisenberg antiferromagnet — •Hyein Jung[1,2], Abeer Arora[2], Victoria Taylor[2], Túlio de Castro[2], Franziska Walther[3], Kristin Kliemt[3], Christian Schüssler-Langeheine[4], Niko Pontius[4], Urs Staub[5], Cornelius Krellner[3], Laurenz Rettig[2], Ralph Ernstorfer[1,2], and Yoav William Windsor[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [3]Goethe-Universität Frankfurt, Frankfurt, Germany — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [5]Paul Scherrer Institut, Villigen, Switzerland

Ultrafast control of spin order holds great promise for future devices. In particular, Eu-based magnetism is appealing due Eu's extremely high moment size. However, the spatially localized 4f magnetic states interact indirectly, mediated by the conduction electrons via Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction. Control of RKKY presents a new avenue for manipulation of spin order, which is of great need particularly for manipulation of antiferromagnets, which are largely considered the basis for next-generation spintronics. Here, we study ultrafast spin dynamics in the chiral antiferromagnet (AF) $EuCo_2P_2$ using resonant X-ray diffraction. We probe two magnetic observables: the size of the AF-ordered spins and their periodicity. We demonstrate that following ultrafast photoexcitation, they depart from the expected thermal behavior, revealing distinct nonthermal dynamics in magnon population and strength of the RKKY coupling between Eu 4f states.

MA 3.9 Mon 12:00 H 2013

Femtosecond spin-state switching in Fe(II) spin-crossover thin films — •Lea Kämmerer[1], G. Kämmerer[1], M. Gruber[1], J. Grunwald[2], T. Lojewski[1], L. Mercadier[3], L. Le Guyader[3], R. Carley[3], C. Carinan[3], N. Gerasimova[3], D. Hickin[3], B. E. Van Kuiken[3], G. Mercurio[3], M. Teichmann[3], S. K. Kuppusamy[4], A. Scherz[3], M. Ruben[4,5], K. Sokolowski-Tinten[1], A. Eschenlohr[1], K. Ollefs[1], C. Schmitz-Antoniak[6], F. Tuczek[2], P. Kratzer[1], U. Bovensiepen[1], and H. Wende[1] — [1]University of Duisburg-Essen and CENIDE — [2]Christian-Albrechts-University Kiel — [3]European XFEL — [4]Karlsruhe Institute for Technology — [5]Institut de Science et d*Ingénierie Supramoléculaires (ISIS) Strasbourg Cedex — [6]Technical University of Applied Science Wildau

Spin-crossover molecules have gained popularity in recent years due to their potential applications, including molecular switches. Understanding their switching dynamics is crucial for optimizing their properties, which involve an abrupt, broad thermal hysteresis as a result of cooperative switching at room temperature. X-ray absorption spectroscopy is a sensitive tool for studying the spin-state. Combining X-ray absorption spectroscopy with a femtosecond time-resolution at the European XFEL allowed observation of the underlying femtosecond switching dynamics in Fe(II) spin-crossover thin films. Optical laser pumping triggered the sub-picosecond light-induced low-spin to high-spin transition in this experiment. A detailed analysis of the dynamics reveals the transient population of an intermediate state.

MA 3.10 Mon 12:15 H 2013

Coupled spin-lattice dynamics from electronic structure — Ramon Cardias[1], Simon Streib[2], Zhiwei Lu[3], Manuel Pereiro[2], Anders Bergman[2], Erik Sjöqvist[2], Cyrille Barreteau[4], Anna Delin[3,2], Olle Eriksson[2], and •Danny Thonig[5,2] — [1]Universidade Federal Fluminense, Brazil — [2]University Uppsala, Uppsala — [3]KTH Royal Institute of Technology, Sweden — [4]Université Paris-Saclay, France — [5]Örebro University, Sweden

The interplay between spin and lattice degrees of freedom is important for a wide range of applications in, e.g., sustainable materials research or in ultrafast dynamics [1]. The here often used low-order parameterised energy description, however, is recently discussed to fail in particular at finite temperature [2].
We developed [3] a method that performs the coupled adiabatic spin and lattice dynamics based on the tight-binding electronic structure model, where the intrinsic magnetic field and ionic forces are calculated from the converged self-consistent electronic structure at every time step. By doing so, this method, implemented in *Cahmd* [4], allows us to explore limits of a given spin-lattice Hamiltonian.
We demonstrate how the dynamics of spin and lattice is strongly influenced by each other on the application to low-dimensional systems. For instance, we observed that a disordered magnetic configuration is able the induce significant lattice distortions.
[1] Phys. Rev. Lett. 76, 4250 (1996); Phys. Rev. B 95, 014431 (2017). [2] Sci. Rep. 10, 20339 (2020); Comp. Mat. Sci. 44, 888 (2009) [3] arXiv:2311.00765 [4] available at https://cahmd.gitlab.io/cahmdweb/.

MA 3.11 Mon 12:30 H 2013

Ultrafast dynamics of phase transitions in hematite — •Maik Kerstingskötter[1], Tobias Dannegger[1], András Deák[2], Levente Rózsa[3], László Szunyogh[2], and Ulrich Nowak[1] — [1]Department of Physics, University of Konstanz — [2]Department of Theoretical Physics, Budapest University of Technology and Economics — [3]HUN-REN Wigner Research Centre for Physics, Budapest

The iron oxide hematite is well suited for many spintronic applications and long-distance spin transport due to its insulating and antiferromagnetic properties and its low damping constant. In addition, hematite undergoes a low-temperature first-order phase transition called the Morin transition, leading to an abrupt 90° spin reorientation associated with a transition from a fully antiferromagnetic to a canted state with weak net magnetization. We simulate the nonequilibrium spin dynamics of this phase transition in response to sudden temperature and field variations with femtosecond resolution using atomistic spin dynamics simulations based on ab initio parameters [1].
[1] T. Dannegger et al., "Magnetic properties of hematite revealed by an ab initio parameterized spin model", *Phys. Rev. B*, **107**, 184426 (2023).

MA 4: Magnetic Heusler Compounds and Complex Magnetic Oxides

Time: Monday 9:30–12:30 Location: EB 107

MA 4.1 Mon 9:30 EB 107

Impact of d-d hybridization on the magnetic and vibrational properties of Ni(-Co)-Mn-Ti: Comparison with p-d Ni-Mn-(In,Sn) — •Olga Miroshkina[1], Benedikt Eggert[1], Johanna Lill[1], Benedikt Beckmann[2], David Koch[2], Katharina Ollefs[1], Franziska Scheibel[2], Wolfgang Donner[2], Oliver Gutfleisch[2], Heiko Wende[1], and Markus E. Gruner[1] — [1]University of Duisburg-Essen, Duisburg, Germany — [2]Technical University of Darmstadt, Darmstadt, Germany

All-d-metal Heusler alloys are a new class of promising magnetocaloric materials for magnetic cooling devices. We study the effect of d-d hybridization on the magnetic and vibrational properties of Ni(-Co)-Mn-Ti in the framework of density functional theory. To retrieve traces of d-d orbital hybridization in L_3-edge spectra, we compare calculated densities of states and x-ray absorption spectroscopy with the case of Ni-Mn-(In,Sn). In our recent studies for Ni-Mn-(In,Sn) [1, 2], we have shown that p-element concentration, together with positional disorder, indirectly affects the magnetic exchange between the 3d-metal atoms. This can be employed to control the magnetization of the transition metal sublattice. Comparison of Ni(-Co)-Mn-Ti with the Ni-Mn-(In,Sn) allows us to reveal the impact of d-element on magnetic characteristics. We show how the interatomic hybridization in all-d-metal Heusler compounds can be exploited as an intrinsic tuning parameter to design high-performance magnetocaloric materials.

[1] F. Cugini *et al.*, *Phys. Rev. B* **105**, 174434 (2022).
[2] O. Miroshkina *et al.*, *Phys. Rev. B* **106**, 214302 (2022).

MA 4.2 Mon 9:45 EB 107

Exploring non-collinear ground states in Mn_2RhSn and Mn_2IrSn Heusler Magnets — •Jorge Cardenas-Gamboa[1], Rebeca Ibarra[1], Paul McClarty[2], Markou Anastasios[3], Edouard Lesne[1], Maia Vergniory[1,4], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Physics Department, University of Ioannina, 45110 Ioannina, Greece — [4]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain

Non-collinear magnetism has emerged as a fundamental and experimentally intriguing aspect of magnetism as one of the most non trivial aspects because of novel topological spin textures (skyrmions) and its potential applications in spintronic devices. Experiments on $Mn2RhSn$ have reported an unusual ground state with magnetic canting and a temperature-induced transition into the collinear ferrimagnetic mode.

In this work, we employ first-principles calculations to implement a mean-field approximation of the ground state in Mn_2RhSn and Mn_2IrSn compounds. This computational approach aims to provide deeper insights into exchange interactions and the magnetic orientation behaviour observed in the experiments.

MA 4.3 Mon 10:00 EB 107

Investigation of the relationship between structural, magnetic and electrical transport properties of $Mn_2Rh_{1-x}Ir_xSn$ epitaxial Heusler thin films: experiments and theory — •Edouard Lesne[1], Rebeca Ibarra[1], Jorge Cardenas[1], Paul A. McClarty[2], Maia G. Vergniory[1], Anastasios Markou[1,3], and Claudia Felser[1] — [1]Max-Planck-Institute für Chemische Physik fester Stoffe, Dresden, Germany — [2]Max-Planck-Institute für Physik komplexer Systeme, Dresden, Germany — [3]Physics Department, University of Ioannina, Ioannina, Greece

The noncentrosymmetric $Mn_2Rh_{1-x}Ir_xSn$ Heusler system which exhibits a noncollinear ferrimagnetic groundstate and is characterized by a D_{2d} symmetry has been in the focus of attention since the independent observation of magnetic skyrmion (Sk) and antiskyrmion (aSk) quasiparticles by real-space imaging techniques, and further inferred from their topological electrical transport footprint to the Hall effect.

Here we investigate the intertwined structural, magnetic, and electrical transport properties of the compositional series $Mn_2Rh_{1-x}Ir_xSn$ epitaxial thin films (with: $0 \leq x \leq 0.4$) grown by magnetron sputtering. In particular we report on an unusual nonmomotonic and sign-changing temperature dependence of the anomalous conductivity (AHC) in all investigated samples. Our results are discussed in light of a combined tight-binding, density functional and mean-field theory approach, which predict the magnetic groundstate of the system and the magnitude of the intrinsic part of the AHC.

MA 4.4 Mon 10:15 EB 107

The role of correlated Jahn-Teller polarons in the dynamics of laser-induced insulator-metal transitions — Tim Titze[1], Maximilian Staabs[1], Pia Henning[1], Karen Stroh[1], Stefan Mathias[1,2], Vasily Moshnyaga[1], and •Daniel Steil[1] — [1]Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany — [2]Universität Göttingen, International Center for Advanced Studies of Energy Conversion (ICASEC), 37077 Göttingen, Germany

We explore the roles of the transition order and phase separation on quasiparticle and spin dynamics in colossal magnetoresistive $(La_{0.6}Pr_{0.4})_{0.7}Ca_{0.3}MnO_3$ (LPCMO) and $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) thin films. LPCMO with a 1^{st} order phase transition is characterized by a strongly nonthermal, metastable response after nanosecond pulsed optical excitation close to the metal-insulator transition, leading to short-term transient metallization and a long-term conductivity decrease. The dynamics in LCMO (2^{nd} order phase transition) are dominantly thermally driven and show a fast recovery of the ground state. Our results highlight that the order of phase transition and the related nanoscale phase separation (JT polarons) play a crucial role for the persistence of laser-excited states in otherwise similar compounds.

Financial support by the DFG within CRC1073 project A02 is gratefully acknowledged.

MA 4.5 Mon 10:30 EB 107

Quasi two dimensional antiferromagnetism in square planar iridate $Cs_2Na_2IrO_4$ — •Roumita Roy[1] and Sudipta Kanungo[2] — [1]Indian Institute of Technology Goa, India — [2]Indian Institute of Technology Goa, India

The study of iridates has gained major attention in recent times, as it is a promising candidate to study the the delicate interplay amongst competing energy scales. However the constant focus has been on Ir in the octahedral or tetrahedral environment. In this work we report the rare occurrence of square planar iridate $Cs_2Na_2IrO_4$. The structure consists of isolated IrO_4 planes, orthogonally oriented in consecutive layers. Our work involves the detailed study of electronic and magnetic properties of $Cs_2Na_2IrO_4$, from first principles calculations. Microscopic magnetic exchange interactions and Wannier function analysis reveals the quasi two dimensional canted AFM ground state, despite the absence of long range structural connectivity which originates because of very weak spin-phonon coupling. Further, the origin of orthogonally placed IrO_4 moieties can be understood from the phonon modes analysis. Belonging to the 5d series, Ir is known to be substantially impacted by SOC. However due to the half-filled situation, the orbital magnetic moment is quenched in this case. Nevertheless we still obtain a large magneto-crystalline anisotropy which could be explained from the second-order perturbation theory. As a guiding tool to experimentalists, we also report preliminary work on muon active sites which is crucial in obtaining the magnetic structure of the system for future studies.

MA 4.6 Mon 10:45 EB 107

Magnetic excitations beyond the single- and double-magnons — •Hebatalla Elnaggar[1], Abhishek Nag[2], Maurits Haverkort[3], Ke-Jin Zhou[2], and Frank de Groot[4] — [1]Sorbonne University - CNRS, Paris, France — [2]Diamond Light Source, Didcot, UK — [3]Heidelberg University, Heidelberg, Germany — [4]Utrecht University, Utrecht, Netherlands

Conventional wisdom suggests that one photon that carries one unit of angular momentum ($1\hbar$) can change the spin angular momentum of a magnetic site with one unit ($\delta M_s = 1 \pm 1\hbar$) at most following the selection rules. This implies that a two-photon process such as 2p3d resonant inelastic X-ray scattering (RIXS) can change the spin angular momentum of a magnetic system with a maximum of two units ($\delta M_s = \pm 2\hbar$). Hereinwe describe a triple-magnon excitation in α-Fe_2O_3, which contradicts this conventional wisdom that only 1- and 2-magnon excitations are possible in a resonant inelastic X-ray scattering experiment [1]. We observe an excitation at exactly three times the magnon energy, along with additional excitations at four and five times the magnon energy, suggesting quadruple and quintuple magnons as well. Guided by theoretical calculations, we reveal how a two-photon scattering process can create exotic higher-rank magnons and the relevance of these quasiparticles for magnon-based applications.

References: 1- H. Elnaggar, et. al., Magnetic excitations beyond the single- and double-magnons, Nat. Commun. 14, 2749 (2023).

15 min. break

MA 4.7 Mon 11:15 EB 107

Large thermal Hall effect in the ordered phase of $EuTiO_3$ — •Rohit Sharma, Johannes Engelmayer, Lara Pätzold, and Thomas Lorenz — II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany

We present the observation of a large thermal Hall effect in the quantum paraelectric compound $EuTiO_3$. Additionally, in $EuTiO_3$ the magnetic moments of Eu^{2+} order antiferromagnetically in a G-type configuration at $T_N \approx 5.5$ K [1]. A magnetic field of ≈ 1.5T is already sufficient to change from antiferromagnetic to polarized ferromagnetic state. We have observed a glasslike longitudinal thermal conductivity (κ_{xx}) in this material, which can be attributed to spin lattice coupling [2]. Temperature dependence of transverse thermal Hall conductivity (κ_{xy}) looks similar to κ_{xx} in the paramagnetic regime. Field dependence of κ_{xy} shows linear behaviour with a positive sign in the paramagnetic regime, but becomes very large with a highly non-monotonic when measured in the ordered phase. It shows a large negative signal in the low field range which changes sign to a small positive signal for high field values. The positive signal at higher field values can be scaled well with the magnetization data measured at same temperature. The origin of the large negative signal is not clear and possible reasons for the its occurrence in $EuTiO_3$ will be discussed.

Funded by the DFG via Project No. LO 818/6-1.
[1] J. Engelmayer et al. Phys. Rev. Mater. 3, 051401(R) (2019)
[2] A. Jaoui et al. Phys. Rev. Mater. 7, 094604 (2023)

MA 4.8 Mon 11:30 EB 107

Janh-Teller bipolarons in the spin-orbit multipolar magnetic oxide Ba_2NaOsO_6 — •Lorenzo Celiberti[1] and Cesare Franchini[1,2] — [1]Faculty of Physics and Center for Computational Materials Science, University of Vienna, Vienna, Austria — [2]Department of Physics and Astronomy 'Augusto Righi', University of Bologna, Bologna, Italy

Complex oxides hosting 5d electrons present a variety of exotic phases arising from spin-orbital (SO) interactions and electronic correlation (EC). In the Mott insulator Ba_2NaOsO_6 (BNOO), a canted antiferromagnet with multipolar interactions, strong EC together with Jahn-Teller lattice activity pave the way for bridging polarons and SO coupling, distinct quantum effects that play a critical role in charge transport and spin-orbitronics. Polarons are quasiparticles originating from strong electron-phonon interaction and are ubiquitous in polarizable materials, especially in 3d transition metal oxides. Despite the more spatially delocalized nature of 5d electrons, we demonstrate the formation of *Jahn-Teller spin-orbital bipolarons* in electron doped BNOO by combining ab-initio calculations with nuclear magnetic resonance and muon spin rotation measurements. The polaronic charge trapping process converts the Os $5d^1$ spin-orbital $J_{\rm eff} = 3/2$ levels, characteristic of pristine BNOO, into a $5d^2$ $J_{\rm eff} = 2$ manifold, leading to the coexistence of different J-effective states in a single-phase material. Moreover, we suggest that polaron formation creates robust in-gap states that prevent the transition to a metal phase even at ultrahigh doping, thus preserving the Mott gap across the entire doping range.

MA 4.9 Mon 11:45 EB 107

Multipolar interactions as the origin of excitation gap in d^3 spin-orbit double perovskites — •Leonid Pourovskii — CPHT, CNRS, École polytechnique, Institut Polytechnique de Paris, 91120 Palaiseau, France — Collège de France, Université PSL, 11 pl. Marcelin Berthelot, 75005 Paris, France

In Mott insulators with a half-filled t_{2g} shell the Hund's rule coupling J_H induces a spin S=3/2 orbital-singlet ground state. The spin-orbit interaction is not effective within this ground state and conventional spin orders are expected. This is the case in d^3 cubic double perovskites (DP) of heavy transition metals. However, their inelastic neutron scattering (INS) spectra feature unexpectedly large gaps. Even in the cubic DP $Ba_2YB'O_6$ (B'=Os, Ru), where single-ion anisotropy is expected to be negligible, the measured gaps are remarkably large. We employ an ab initio many-body force-theorem method to obtain effective magnetic Hamiltonians for these two systems. The calculated Hamiltonains feature unexpectedly significant multipolar - dipole-octupolar (DO) - intersite exchange interactions. The DO terms break continuous symmetry of the S=3/2 Heisenberg terms opening an excitation gap. The theoretical gap magnitudes and calculated INS spectra agree with experiment. The DO intersite coupling arises due to excited states of the t_{2g}^3 manifold admixed by spin-orbit into the $S = 3/2$ ground state. Their large relative magnitude stems from a characteristic anisotropy of t_{2g} hopping terms in DPs and scales as a square of the ratio of spin-orbit coupling and J_H.

MA 4.10 Mon 12:00 EB 107

Magnetic and lattice properties of KEr(MoO4)2 in magnetic fields up to 50 tesla — •D. Kamenskyi[1], L. Prodan[1], K. Kutko[2], V. Khrustalyov[2], S. Khmelevskyi[3], L. Pourovskii[4], B. Bernath[5], and Y. Skourski[6] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg — [2]B. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, Kharkiv, Ukraine — [3]Research Center for Materials Science and Engineering, Vienna University of Technology, Austria — [4]CPHT, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, France — [5]HFML-EMFL, Radboud University, Nijmegen, The Netherlands — [6]HLD-EMFL, Helmholtz-Zentrum Dresden-Rossendorf, Germany

We report a magnetisation and magnetosriction study of the rare-earth-based paramagnet KEr(MoO4)2 in magnetic fields up to 50 T. Recent observation of massive magnetostriction and rotational magnetocaloric effects triggered the interest to study the microscopic mechanism behind this phenomena. We combine several experimental techniques to investigate the magnetisation behaviour until saturation. The synergy of magnetic torque measurements and vibrating sample magnetometry allowed us to reconstruct parallel and perpendicular magnetisation, enabling us to trace its evolution up to 30 T. Our experiments reveal the saturation along all principle axes is well below the value expected from crystal electric field calculations. We argue that an applied magnetic field distorts the local environment of Er3+ ions and affects its crystal electric field splitting.

MA 4.11 Mon 12:15 EB 107

Tuning the physical properties of La0.7Sr0.3MnO(3-δ) via oxygen off-stoichiometry using assisted thermal vacuum annealing — •Chenyang Yin[1,2], Lei Cao[2], Suqin He[3,2], Tomas Duchon[4], Yunxia Zhou[5], Denis Sheptyakov[6], Maria Teresa Fernandez-Diaz[7], Shibabrata Nandi[2], and Oleg Petracic[2,1] — [1]Heinrich Heine University Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany — [2]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Peter Grünberg Institut (PGI-7), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [4]Peter Grünberg Institut (PGI-6), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [5]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [6]Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [7]Institut Laue-Langevin (ILL), Grenoble, France

In La0.7Sr0.3MnO(3-δ) (LSMO), the topotactic phase transition from the Perovskite (PV) phase to the layered oxygen-vacancy-ordered Brownmillerite (BM) phase can be triggered by deoxygenation. We realized this phase transition in both a strained LSMO thin film system and bulk-like unstrained LSMO powder system via assisted thermal vacuum annealing. For thin film, A metal-to-insulator and simultaneously a ferromagnetic-to-antiferromagnetic transition is found. For powder, the evolution of crystal and spin structure at different oxygen-deficient states from PV to BM is determined using neutron diffraction.

MA 5: Spin Structures and Magnetic Phase Transitions I

Time: Monday 9:30–12:45 Location: EB 202

MA 5.1 Mon 9:30 EB 202

Exploring and Tuning Magnetic Order in Rare-Earth Tritellurides — •Thom Ottenbros[1], Claudius Mueller[1,2], Shiming Lei[3,5], Ratnadwip Shingha[4,5], Leslie Schoop[5], Nigel Hussey[1,6], and Steffen Wiedmann[1] — [1]HFML-FELIX, Radboud University, Nijmegen, The Netherlands — [2]UT, Enschede, The Netherlands — [3]HKUST, Hong Kong — [4]IITG, Guwahati, India — [5]Princeton University, New Jersey, USA — [6]HH Wills, Bristol, UK

In recent years, a new class of layered antiferromagnetic (AFM) materials has appeared that consist of alternating stacks of localized, magnetically ordered and itinerant, non-magnetic electrons, giving rise to rich phase diagrams in which spin and charge degrees of freedom play a central role. In the rare-earth tritelluride RTe3 family, this interplay between the spin and charge interactions is particularly complex, with the itinerant 5p Te electrons undergoing a charge density wave transition at elevated temperatures.

In this work, we present thermal expansion (TE) and high-field magnetostriction (MS) studies on GdTe3, the ideal candidate material to investigate the cascade of AFM ordered phases due to the relatively high transition temperatures with a suspected striped AFM spin structure. We present MS data along different high-symmetry orientations and demonstrate that out-of-plane uniaxial strain alters the magnetic phase diagram. Finally, from analysis of the quantum oscillations in the MS, we find evidence for a strain-induced Fermi surface reconstruction. Our results demonstrate the remarkable complexity and tunability of the ordered magnetic states and spin structures in GdTe3.

MA 5.2 Mon 9:45 EB 202

Generalization of Dzyaloshinskii-Moriya interaction to any beyond Heisenberg spin model — •Hiroshi Katsumoto[1], Yuriy Mokrousov[1,2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

In the past decade, it has become clear that the competition between Heisenberg and higher-order exchange interactions can promote very complex magnetic structures. While higher-order terms among isotropic exchange interactions are known to stem not only from the number of sites but also from the spin magnitude [1], Moriya derived the Dyzaloshinskii-Moriya interaction (DMI), which has emerged as a key mechanism to stabilize chiral magnetism, only for spin-1/2 systems. Starting from a fermionic model and applying perturbation theory to the first order in the spin-orbit coupling, we generalized Moriya's work and derived an expression that generates the DMI sequentially for any higher-order exchange interaction. The application of this expression to particular spin models provides consistently all recently suggested DMIs extended to higher-order exchange interactions [2].

We acknowledge funding from the ERC grant 856538 (project "3D MAGIC"), and DFG through SPP-2137 and SFB-1238 (project C1).

[1] M. Hoffmann *et al.*, PRB **101**, 024418 (2020).

[2] A. Lászlóffy *et al.*, PRB **99**, 184430 (2019); S. Brinker *et al.*, NJP **21**, 083015 (2019); S. Grytsiuk *et al.*, Nat. Commun. **11**, 511 (2020); S. Mankovsky *et al.*, PRB **101**, 174401 (2020).

MA 5.3 Mon 10:00 EB 202

Generalization of Lieb's Theorem to a Class of Non-Bipartite Lattice Structures — •Fabio Pablo Miguel Méndez Córdoba[1,2,3], Joseph Tindall[4], Dieter Jaksch[2,5], and Frank Schlawin[2,3,6] — [1]Departamento de Física, Universidad de Los Andes, A.A. 4976, Bogotá, Colombia — [2]Universität Hamburg, Luruper Chaussee 149, Gebäude 69, D-22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg D-22761, Germany — [4]Center for Computational Quantum Physics, Flatiron Institute, 162 5th Avenue, New York, NY 10010 — [5]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [6]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany

Lieb's theorem is of fundamental importance for our understanding of correlated magnetic systems. It predicts the ground state magnetization and magnetic order for interacting itinerant electrons by establishing the connection between the magnetic properties of the Hubbard and Heisenberg models. However, Lieb's theorem is valid only for bipartite lattices. In this work, we extend the theorem to a class of non-bipartite lattices by reinterpreting the lattice structure as a collection of disconnected bipartite subsystems. This extension allows for accurately predicting the emergent magnetic structure, which the corresponding Heisenberg model misses.

MA 5.4 Mon 10:15 EB 202

Thermal phase transitions of a spin-1/2 Ising-Heisenberg model on the extended Lieb lattice in a magnetic field — •Jozef Strecka and David Sivy — Faculty of Science, P. J. Safarik University, Kosice, Slovakia

The spin-1/2 Ising-Heisenberg model on the extended Lieb lattice can be rigorously mapped in presence of the external magnetic field to an effective spin-1/2 Ising square lattice with temperature-dependent interaction and field. It is shown that an effective field may vanish along a phase boundary between a quantum monomer-dimer phase and a classical ferrimagnetic phase, which allows an exact determination of thermal phase transitions between these two phases even in presence of non-zero magnetic field. Similar thermal phase transitions can be additionally found between a quantum antiferromagnetic phase and a disordered paramagnetic phase of the model. It is demonstrated that the line of discontinuous phase transitions terminates at the Ising critical point corresponding to a continuous phase transition. The aforementioned exact results for discontinuous and continuous thermal phase transitions in a magnetic field are corroborated by classical Monte Carlo simulations.

This work is supported by Slovak Research and Development Agency under the contract No. APVV-20-0150.

MA 5.5 Mon 10:30 EB 202

Investigation of the first-order antiferromagnetic phase transition of $SrMn_2P_2$ and $CaMn_2P_2$ by thermal-expansion measurements with controlled force — •Sven Graus, N. S. Sangeetha, Teslin R. Thomas, Maximilian van de Loo, Andreas Kreyssig, and Anna E. Böhmer — Experimentalphysik IV, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

$SrMn_2P_2$ and $CaMn_2P_2$ adopt a trigonal layered structure with Mn-atoms on a corrugated honeycomb lattice and show insulating behavior. $CaMn_2P_2$ has an antiferromagnetic transition at $T_N = 70$ K of strong first-order character and $SrMn_2P_2$ exhibits a weak first-order antiferromagnetic transition at the Néel temperature $T_N = 53$ K [1]. These first-order antiferromagnetic transitions are unique among the class of Mn-based 122-compounds and their mechanism remains to be explained. It is possibly related to structural changes. We perform high-resolution thermal-expansion measurements by capacitance dilatometry around these phase transitions. In these dilatometry measurements a controlled force in a specific crystallographic direction is applied, varying from ∼0.5 N up to several N. This presents a highly sensitive approach to investigate possible lattice distortions or changes of elastic moduli.

We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG) under CRC/TRR 288 (Project A02).

[1] Sangeetha et al., PNAS **118**, e2108724118 (2021).

MA 5.6 Mon 10:45 EB 202

The role of quantum fluctuations for the spin-flop transition in hematite — •Tobias Dannegger and Ulrich Nowak — Fachbereich Physik, Universität Konstanz

Hematite is a canted antiferromagnet with promising properties for spintronics applications such as long range spin transport. At higher temperatures, its equilibrium properties and phase transitions are well described by a semiclassical spin model, but towards low temperatures, qualitative differences between the predictions of a classical model and experimental results arise [1]. Here, we explore how quantum effects can account for those differences using mean-field calculations and exact diagonalisation of the quantum Heisenberg Hamiltonian. Based on an ab initio parametrised model, we compute low-temperature spin-flop fields and compare them to classical calculations and measurements on a hematite single-crystal.

[1] T. Dannegger et al., *Phys. Rev. B* **107**, 184426 (2023).

15 min. break

MA 5.7 Mon 11:15 EB 202

Kosterlitz-Thouless transition in the finite 2DXY model with 4-fold anisotropy — •David Venus — McMaster University, Hamilton, Canada

The RG equations for the infinite 2DXY model with 4-fold anisotropy under geometric scaling, are linearized about their fixed point, and then solved exactly for a finite system by integration up to a system size L. The solution demonstrates that the finite anisotropic 2DXY system: a) does not exhibit a non-universal 2nd-order transition observed in the infinite system; b) is characterized by a product of the anisotropy and $\ln L$; c) with small anisotropy flows past the critical point and exhibits a KT transition; d) with large anisotropy flows to an Ising transition.

The solution near the critical point validates a perturbative approach in small 4-fold anisotropy appropriate, for instance, for ferromagnetic films. This gives quantitative results for the coupling, vortex fugacity and effective 4-fold anisotropy across the entire finite-size transition. In particular, the coupling has a universal point of inflection where vortex-antivortex pairs unbind, as opposed to the "universal jump" seen in the infinite, isotropic system.

MA 5.8 Mon 11:30 EB 202

The zoo of states in the 2D Hubbard model — •Robin Scholle, Pietro Bonetti, Demetrio Vilardi, and Walter Metzner — MPI for Solid State Research, Stuttgart, Germany

We use real-space Hartree-Fock theory to unbiasedly construct a phase diagram of the 2D Hubbard model in temperature and doping. We are able to detect various spin- and charge order patterns including Néel, stripe and spiral order. I will give a short summary of the method followed by a presentation of our current results and a possible outlook for further applications.

MA 5.9 Mon 11:45 EB 202

Magnetic phase transitions in $TbFeO_3$ — •Johanna Jochum[1], Michal Stekiel[2], Alexander Engelhardt[3], Astrid Schneidewind[2], and Christian Pfleiderer[1,3] — [1]Heinz Maier-Leibnitz Zentrum, Technische Universität München, 85748 Garching — [2]JCNS-MLZ, Forschungszentrum Jülich GmbH, Outstation Garching, 85748 Garching — [3]Physik Department, Technische Universität München, 85748 Garching

Rarearth (RE) orthoferrite have been studied widely due to their multiferroic properties [1] on the one hand and on the other hand owing to a series of magnetic transitions, which follow from the interaction between the magnetic sublattices of the Fe and RE atoms [2]. The latter manifests in partial ordering and spin reorientation transitions of these sublattices. $TbFeO_3$ in particular, shows two spin-reorientation transitions. In the high temperature phase (HT) only the Fe sublattice is magnetically ordered. At the first transition, the Fe sublattice polarizes the Tb ions leading to a rotation of the spins of both system towards the crystallographic b axis (IT). At 3K the Tb sublattice orders antiferromagnetically, and the Fe sublattice returns to its high temperature state (LT) [3]. We have studied these spin-reorientation transitions in $TbFeO_3$ as a function of magnetic field using neutron diffraction. The data suggest that the transition from HT to the IT is suppressed as the magnetic field isincrease, leading to strong fluctuations that extend to temperatures beyond the zero field transition.

[1] Y. Ke, et al., Sci. Rep. 6, 19775 (2016) [2] R. L. White, JAP 40, 1061 (1969) [3] A. K. Ovsianikov et al., JMMM 563 170025 (2022)

MA 5.10 Mon 12:00 EB 202

Origin of the antiparallel spin coupling of a $Nd_3Fe_3Sb_7$ single crystal. — •Sabrina Palazzese[1,4], F. Pabst[3], Sh. Yamamoto[1], K. Kummer[2], D. Gorbunov[1], S. Chattopadhyay[1], T. Herrmannsdoerfer[1], M. Richter[5], R. Ray[5], M. Ruck[3], E. Weschke[6], O. Prokhnenko[6], B. Lake[6], and J. Wosnitza[1,4] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden — [2]European Synchrotron Radiation Facility (ESRF) — [3]Fakultät für Chemie und Lebensmittelchemie, TU Dresden — [4]Institut für Festkörper- und Materialphysik, TU Dresden — [5]Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) — [6]Helmholtz-Zentrum Berlin (HZB)

We investigated $Nd_3Fe_3Sb_7$ using SQUID magnetometry and X-ray magnetic circular dichroism. Previous studies on polycrystalline samples show that $Nd_3Fe_3Sb_7$ exhibits a rather complex magnetism [1]. We found an unusual antiparallel coupling between the magnetic moments of Nd $4f$ and Fe $3d$ along the c-axis. This is also observed in the isostructural compound $Pr_3Fe_3Sb_7$, as demonstrated by neutron diffraction [2], but the origin of this behavior has not been further elucidated. The compound shows ferrimagnetic ordering below the spin-reorientation transition and planar magnetic anisotropy above it. DFT calculations indicate an induced magnetic moment in the Sb atoms. We attribute the antiparallel coupling to a potential superexchange interaction mediated by the Sb atoms.

[1] N. Nasir, *et al.*, *Intermetallics* **18**, 2361 (2010).
[2] F. Pabst, *et al.*, *Adv. Mat.* **35**, 2207945 (2023).

MA 5.11 Mon 12:15 EB 202

On the valence of chalcogen spinels — •Vinícius Estevo Silva Frehse, Aleksander Sukhanov, Elaheh Sadrollahi, and Marein Rahn — IFMP, Dresden, Germany

The valence characteristics in the metallic ferromagnetic spinels CuCr2X4 (X = S, Se, Te) has long been subject to debate. At the heart of this controversy lies the ambiguity between two scenarios, proposed by F. K. Lotgering and J. B. Goodenough: According to Lotgering, monovalent non-magnetic Cu ions (3d10) exist next to mixed-valent (3+/4+) Cr with a reduced magnetic moment. Conversely, in the Goodenough model, Cu is divalent (3d9), with an anti-parallel spin-polarization that partially compensates the Cr3+ magnetism. In the light of potentially competing or almost degenerate valence distributions on a frustrated lattice, it would be of great interest to clarify the order parameter and mechanism of a pronounced low-temperature phase transition that has recently been observed by local and bulk magnetic probes (μSR, NMR and Mössbauer spectroscopy). Surprisingly, we find that magnetic neutron powder diffraction is not sensitive to this transition. A review of past and present experimental evidence provides some constraints on the unusual scenarios that could reconcile this apparent contradiction.

MA 5.12 Mon 12:30 EB 202

The role of magnetoelastic coupling in $GdRu_2Si_2$ and uniaxial pressure effects on the skyrmion-lattice phase — •Lukas Gries[1], Daniel Mayoh[2], George Wood[2], Geetha Balakrishnan[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, University of Warwick, United Kingdom

The centrosymmetric tetragonal antiferromagnet $GdRu_2Si_2$ displays a rich phase diagram including the square magnetic skyrmion lattice phase. Here, we present high-resolution capacitance dilatometry and magnetisation studies on single crystals in external magnetic fields up to 15 T. Our data show significant magneto-elastic coupling as proven by pronounced anomalies in thermal expansion and magnetostriction at the phase boundaries. The clear signatures of the phase boundaries allow us to discover new phases, thereby expanding and complementing the magnetic phase diagram. We qualitatively and quantitatively determine the uniaxial pressure dependencies of the phase boundaries. In particular the skyrmion-lattice phase is enlarged and stabilised in field and temperature by uniaxial pressure applied along the crystallographic c axis.

MA 6: Molecular Magnetism

Time: Monday 9:30–13:00 Location: EB 301

Invited Talk MA 6.1 Mon 9:30 EB 301

Studying single molecule magnets for quantum technologies — •Wolfgang Wernsdorfer — PHI and IQMT, KIT, Karlsruhe, Germany

Single molecule magnets (SMMs) have been proposed for applications in high-density storage, quantum sensing, quantum simulation, quantum computing, and spintronics applications. Bulk magnetometric and spectroscopic techniques of molecular systems have allowed the observation of remarkable quantum effects in SMMs, such as the observation of an energy barrier to the reversal of the magnetisation and quantum tunnelling of the magnetisation Over the past 10 years, scanning tunnelling microscopy of SMMs and single-molecule devices architectures, such as spin valves and spin transistors, have shed light into the quantum properties of SMMs at single molecule level. More recently, new techniques, where the spin-degrees of freedom in SMMs can be readout by photons, are being studied. Here, we review key techniques allowing the observation of quantum effects, important for the initialisation, control and read-out of the states of the SMMs, ultimately leading to the implementation of SMMs is technological applications. In the long term, chemically designed quantum architectures might have the potential to outperform existing platforms in terms of scalability, switchability, controllability, qubit density, and integrability.

MA 6.2 Mon 10:00 EB 301

Study of Landau-Zener transition of electron spin state on Single Ho atom — •Wonjun Jang[1,2], Luciano Colazzo[1,2], Georg A. Traeger[4], Lei Fang[1,2], Fabio Donati[1,3], Chau Bui[1,3], Soo-Hyon Phark[1,3], and Andreas Heinrich[1,3] — [1]Center for Quantum Nanoscience, Institute for Basic Science, Seoul 03760, South Korea — [2]Ewha Womans University, Seoul 03760, South Korea. — [3]Department of Physics, Ewha Womans University, Seoul 03760, Republic of Korea — [4]Physik, Georg-August-Universität, Göttingen, Germany

We report Landua-zener transition of electron spin states of a single Holmium (Ho) atom using spin-polarized scanning tunneling microscopy (STM). Single Ho atom on an oxygen site on MgO results in avoided level crossings due to the crystal field and hyperfine interaction. These avoided level crossings manifest as nuclear spin-mediated Landau-Zener tunneling of the electron spin state. By employing a combination of magnetic field sweeping and spin-polarized scanning tunneling microscopy, we measured the probabilities of electron spin reversal through Landau-Zener tunneling at the avoided level crossing with an energy gap of 5 peV. The maximum probability observed is 16%, influenced by the thermal population of nuclear spin states. Our spin-polarized STM measurement at the specific avoided level crossing enabled the single-shot measurement of the nuclear spin state. This research represents a direct measurement of the time evolution of the nuclear spin state of a rare earth atom.

MA 6.3 Mon 10:15 EB 301

Real-Space Imaging of Triplon Excitations in Engineered Quantum Magnets — •Robert Drost[1], Shawulienu Kezilebieke[2], Jose Lado[1], and Peter Liljeroth[1] — [1]Aalto University, Department of Applied Physics — [2]University of Jyväskylä, Department of Physics, Department of Chemistry, and Nanoscience Center

Despite the absence of long-range order, quantum magnetic ground states result from the inter-actions of spins at the nanoscale. It is thus possible to rationally design quantum magnets with pre-defined properties from simple ingredients. Organo-metallic molecules provide highly flexible spin systems. This flexibility makes them ideal candidate building blocks for designer quantum magnets. One example of fundamental excitations in quantum magnets are triplons. These dispersive triplet modes result form the internal excitations in the building blocks. Here, we show that triplon excitations can be produced in designer quantum systems and probed in real space using scanning tunneling microscopy (STM). We achieve this using assemblies of metal phthalocyanine molecules with an internal singlet-triplet transition. We further show that the dispersion bandwidth of triplons is strongly correlated with the dimensionality of the molecular assembly as expected from dispersive many-body modes. Our experiments show that arrays of metal-organic molecules are efficient platforms to simulate quantum magnets and study their excitations in a simplified setting.

MA 6.4 Mon 10:30 EB 301

High-field/high-frequency electron paramagnetic resonance studies on a muffin-shaped Er(III) complex — •Birte Beier[1], Jan Arneth[1], Gerlinde Greif[2], Peter Roesky[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Institute for inorganic chemistry, Karlsruhe Institute for Technology, Germany

Quantitative determination of magnetic anisotropy and the energy level diagram in $4f$ monomeric complexes is key to design appropriate crystalline environments of the magnetic centers. Here, we report high-field/high-frequency electron paramagnetic resonance spectroscopy (HF-EPR) and magnetisation studies on the phenantrolinpyridin-triazol (PPT) complex $[Er(PPTMP)_2(MeOH)][OTf]_3x3MeOH$ which is characterised by a muffin-shaped first coordination sphere. Our observation of a Kramer's doublet with $g_{\mathrm{eff}} = 8.5(4)$ implies a $m = \frac{7}{2}$ ground state doublet of the 9-fold coordinated Er(III) ion. This conclusion is further supported by high-field magnetisation data. The absence of inter doublet transitions indicates that the gap to the first excited Kramers doublet exceeds 550 GHz. The anisotropic effective g-factors are compared with numerical studies and discussed with respect to related Er(III) complexes.

MA 6.5 Mon 10:45 EB 301

Room Temperature Ferromagnetism in $Tb_3N@C_{80}$ Crystals — •Lebin Yu[1], Shangfeng Yang[2], and Thomas Greber[1] — [1]Physik-Institut, University of Zürich, Zürich, Switzerland — [2]Department of Material Science and Engineering, University of Science and Technology of China, Hefei, China

Endohedral metallofullerenes (EMFs) with paramagnetic ions such as Dy^{3+} or Tb^{3+} provide a unique platform to study a spin system. Typically, magnetic interactions between neighboring carbon cages are neglected in the explanation of magnetic order above 3 K [1]. Unexpectedly, we have observed ferromagnetism at room temperature in cubic crystals of trinuclear nitrogen molecules using SQUID magnetometry. Dissolving the crystals in toluene reduces the remanence. For the dissolved $Tb_3N@C_{80}$ single molecule magnets we find hysteresis at 1.8 K without remanence, which reflects the frustrated ground state like in $Dy_3N@C_{80}$ [2]. Such a manifestation of magnetism implies a new aspect of magnetic properties of endofullerene single molecule magnets.

[1] A. Kostanyan et al. Phys. Rev. B, 101, 134429 (2020).
[2] R. Westerström et al. Phys. Rev. B, 89, 060406(R) (2014).

MA 6.6 Mon 11:00 EB 301

Hybrid Single Molecule Magnet - Metal System Studied with Nitrogen Vacancy Relaxometry — •Julian Skolaut[1], Zhewen Xu[2], Laura van Schie[2], Dominik Laible[1], Andrea Morales[3], Simon Josephy[3], Ashish Moharana[1], Eva Rentschler[1], Christian Degen[2], and Angela Wittmann[1] — [1]Johannes Gutenberg-University, Mainz, Germany — [2]ETH, Zurich, Switzerland — [3]QZabre, Zurich, Switzerland

The unceasing demand for data storage capacity continues to inspire research in the field of magnetism. Single molecule magnets (SMMs) represent a promising avenue for miniaturizing data storage units to nanometer scales.

However, integration of SMMs into devices commonly involves deposition on metal substrates, which poses many challenges. Among these, a critical concern is hybridization, which can severely alter an SMM's magnetic properties to the point of complete quenching. Here, we aim to investigate these hybridization effects on SMMs for spintronics applications.

Our investigations employ relaxometry measurements facilitated by a scanning nitrogen vacancy magnetometry setup. In this, increased magnetic noise from the SMMs leads to a reduced lifetime of the nitrogen vacancy center, providing access to the SMM's magnetic properties. We present first results of relaxometry measurements on metallacrown SMMs on gold surfaces.

15 min. break

MA 6.7 Mon 11:30 EB 301

Time-dependent density functional theory studies of a Fe(II) spin-crossover complex — •Gérald Kämmerer and Peter Kratzer — Faculty of Physics, University of Duisburg-Essen

Motivated by recent time-resolved experiments, we study the spin-state switching of a Fe(II) spin-crossover complex Fe(pypypyr)$_2$ from a diamagnetic low-spin ($S = 0$) to a paramagnetic high-spin ($S = 2$) state in the framework of density functional theory (DFT). The calculations were performed with the FHI-Aims code using PBE and HSE functionals. Due to the switching, the bond length Fe-N increases by up to 10%. In addition, excited state calculations have been performed for the electronically low spin state to understand the mechanism of light-induced switching. Molecular dynamics simulations were performed to further investigate the role of ionic motion in the switching. The financial support of the DFG within the SFB 1242 (project B02) and the computational time on the magnitUDE supercomputer system are gratefully acknowledged

MA 6.8 Mon 11:45 EB 301

Investigation of magnetic 3d-4f interaction in butterfly-shaped V_2Ln_2 complexes — •Jan Arneth[1], Xianfeng Li[2], Jonas Braun[2], Annie Powell[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Institute for Nanotechnology, Karlsruhe Institute for Technology, Germany

On the journey to high-performance single molecular magnets (SMM) heterometallic nanoclusters comprising 3d and 4f metal ions are of immense interest for studying the factors that govern the strength and type of intracluster magnetic coupling between the metal ions. Here we investigate the magnetic anisotropy and interactions in a family of butterfly-shaped molecular V_2Ln_2 (Ln = Y,Tb,Dy,Ho,Er,Tm,Yb) clusters where the V(III) are located on the wingtips and the Ln(III) occupy the body positions. In this series the compounds with Ln = Tb, Dy, Ho and Er show slow relaxation of the magnetisation. Combined magnetic studies and high-field/high-frequency electron paramagnetic resonance (HFEPR) spectroscopy uncover planar anisotropy of the vanadium ion and a weak antiferromagnetic V-V coupling. Furthermore, the data reveal dominant ferromagnetic V-Ln interaction which decreases with increasing number of 4f-electrons.

MA 6.9 Mon 12:00 EB 301

Pressure-induced ordering in a highly symmetric quantum magnet DTN — •Kirill Povarov[1], David Graf[2], Andreas Hauspurg[1,3], Sergei Zherlitsyn[1], Joachim Wosnitza[1,3], Takahiro Sakurai[4], Hitoshi Ohta[5,6], Shojiro Kimura[7], Hiroyuki Nojiri[7], Ovidiu Garlea[8], Andrey Zheludev[9], Armando Paduan-Filho[10], Michael Nicklas[11], and Sergei Zvyagin[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden — [2]National High Magnetic Field Laboratory, Tallahassee — [3]Institut für Festkörper- und Materialphysik, TU Dresden — [4]Research Facility Center for Science and Technology, Kobe U. — [5]Molecular Photoscience Research Center, Kobe U. — [6]Graduate School of Science, Kobe U. — [7]Institute for Materials Research, Tohoku U. — [8]Neutron Scattering Division, ORNL — [9]Laboratory for Solid State Physics, ETH Zürich — [10]Instituto de Fisica, U. de São Paulo — [11]Max Planck Institute for Chemical Physics of Solids

We experimentally demonstrate the pressure-induced ordering in the model tetragonal $S = 1$ quantum paramagnet $NiCl_2{\cdot}4SC(NH_2)_2$ (DTN). Employing TDO susceptibility and ultrasound techniques, we show that the spin gap vanishes and the magnetic order appears at a critical pressure $P_c = 4.2(3)$ kbar. Powder neutron diffraction reveals undistorted tetragonal symmetry at the magnetic criticality. We describe the obtained critical fields employing linear spin-wave theory and a quasi-1D numeric approximation, circumventing the quantum renormalization effects for spin-Hamiltonian parameteres. The studies are complemented by high-pressure ESR measurements.

MA 6.10 Mon 12:15 EB 301

Determination of Directions of the Magnetic Anisotropy Axes of 3d-4f Heterometallic M_2Ln_2 Single-Molecule Magnets by Inelastic Neutron Scattering — •Julius Mutschler[1], Thomas Ruppert[2], Yan Peng[2], Jacques Ollivier[3], Quentin Berrod[3], Jean-Marc Zanotti[3], Christopher E. Anson[2], Annie K. Powell[2], and Oliver Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, D-79104 Freiburg, Germany — [2]Institut of Inorganic Chemistry, Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany — [3]Institut Laue-Langevin, F-38042 Grenoble Cedex 9, France

The discovery of slow relaxation and quantum tunneling of magnetisation in single molecule magnets (SMMs) three decades ago triggered intense research into their magnetic properties. This class of molecules has been extended to heterometallic clusters containing transition metal and rare earth ions. 4f ions are of interest because of their large angular momentum and magnetic anisotropies but also pose a challenge in analyzing inelastic neutron scattering (INS) data. In this work, we present an INS study on non-deuterated powder samples of M_2Ln_2 butterflies with M = Fe, Al and Ln = Dy, Er, obtained with the time-of-flight disk-chopper spectrometers IN5 and IN6-SHARP at the ILL. Our analysis unveils yet another capability of powder INS: The relative directions of magnetic anisotropy axes of 4f ions with respect to the anisotropy axes of the 3d ions could be determined from the experimental data. This allows to test, e.g., ab-initio theory, in unprecedented detail.

MA 6.11 Mon 12:30 EB 301

Deep Learning based Inverse Design of Ligand-Field Parameters of Single-Molecule Magnets — •Zayan Ahsan Ali, Julius Mutschler, and Oliver Waldmann — Physikalisches Institut, Universität Freiburg, D-79104 Freiburg, Germany

Single molecule magnets (SMMs) have attracted a rich volume of research in the recent decades due to their potential applications in magnetic memory and quantum computing. Lanthanide-based SMMs in particular demonstrate promising magnetic retention due to large inherent anisotropies. Their magnetic properties can be parameterized by ligand-field theories involving a set of 27 parameters. Experimental data such as magnetization and susceptibility curves, however, are typically featureless for these materials. Multiple distinct parameter sets can describe the data to equal accuracy, making the determination of model parameters a formidable inverse problem. In this work, the over-parameterization is tackled by implementing a deep learning architecture consisting of a Variational Autoencoder (VAE) in conjunction with an Invertible Neural Network (INN). The VAE-INN architecture determines hidden system parameters of the magnetic data and subsequently relates them to multiple valid model parameters from ligand-field theory. This approach is found to offer significant advantages over conventional fitting routines, such as Levenberg-Marquardt, in terms of generalization and convergence. The study investigates and presents both the merits and the effectiveness of the VAE-INN model in producing consistent sets of ligand-field parameters for novel experimental data.

MA 6.12 Mon 12:45 EB 301

Enhancement and manipulation of quantum entanglement in three-spin clusters by non-conserving magnetization and electric field — •Zhirayr Adamyan[1,2], Vadim Ohanyan[1,2], and Ani Chobanyan[1] — [1]Laboratory of Theoretical Physics, Yerevan State University, 1 Alex Manoogian, 0025 Yerevan, Armenia — [2]CANDLE, Synchrotron Research Institute, 31 Acharyan Str., 0040 Yerevan, Armenia

The quantum entanglement of spin states in molecular magnets has important applications in quantum information technologies and quantum computing. Currently, qubit models based on magnetic molecules are being used to develop quantum computation and communication technologies. We consider two models of three-spin molecular magnets with additional features that allow one to manipulate and enhance their entanglement. The first model is a mixed-spin (1/2, 1, 1/2) triangle with two g-factors. The second model is a spin-1/2 triangle with the Katsura-Nagaosa-Balatsky (KNB) mechanism, providing the coupling between spin degrees of freedom and the external electric field. It is shown that non-conserving magnetization originated from the non-uniformity of g-factors leads to an essential increase of the entanglement of certain spin states along with the rich structure of zero-temperature phase diagrams. Whereas, the model with magnetoelectric coupling due to the KNB mechanism offers a wide possibility of manipulation of quantum entanglement by the electric field, both using its magnitude and direction.

MA 7: Bulk Magnetic Materials and Magnetic Particles/Clusters

Time: Monday 9:30–12:45 Location: EB 407

MA 7.1 Mon 9:30 EB 407

Theoretical Investigation of the Effect of Si and Co Doping on the Physical and Magnetic Properties of Rare-Earth-Free Fe_2P Magnets — •Stephan Erdmann, Halil Ibrahim Sözen, and Thorsten Klüner — Carl von Ossietzky University Oldenburg

Due to the resource criticality of rare-earth (RE) elements, there is a great interest in finding a RE-free magnet to fill in the gap between the commonly used ferrites and the $Nd_2Fe_{14}B$ magnets. A potential candidate to fill in this gap are magnets based on the Fe_2P compound, which exhibits a high magnetisation and high uniaxial anisotropy. In this work, we have performed density functional theory calculations to investigate the influence of the substitution of P and Fe by readily available elements such as Si and Co on the magnetic and physical properties of the Fe_2P compound. Both elements have been chosen because they are known to increase the Curie temperature of Fe_2P. For a systematic understanding, properties such as the formation energy at 0 K, as well as magnetic properties like the magnetization M_S and the Curie temperature T_C are screened starting from the binary structure of Fe_2P. Furthermore, the combined effects of Si and Co substitution on the physical and magnetic properties are considered in quarternary $(Fe,Co)_2(P,Si)$ compounds. The T_C trends of these quarternary compounds were investigated by the calculation of exchange interaction energies J_{ij}, which revealed a positive influence of Si on the 3f-3g Fe interactions leading to an increase in T_C. Co substitution leads either to an increase or decrease of the 3f-3f and 3g-3g Fe interactions and thus on T_C for low and high Si contents, respectively.

MA 7.2 Mon 9:45 EB 407

A magnetic C36 Laves phase in Co-Fe-Ta system — •Sergiu Arapan[1], Pablo Nieves[2], Jakub Šebesta[3], Andrea Dzubinska[4], Marian Reiffers[5], and Dominik Legut[1] — [1]VŠB - Technical University of Ostrava, Czech Republic — [2]University of Oviedo, Spain — [3]Uppsala University, Sweden — [4]University Pavol Jozef Safarik, Košice, Slovakia — [5]University of Prešov, Slovakia

Modern computational tools that use a combination of electronic structure calculations, adaptive genetic algorithms, and machine learning data analysis, allow for an unprecedented prediction of new structures with desired physical properties. Yet, in many cases, no recipes are provided to synthesize them. In the case of a binary compound, we show a route to bring a theoretically predicted structure to a real material. In particular, we demonstrated the possibility to synthesize a C36 Laves phase (hP24 structure) with improved intrinsic magnetic properties in the Co-Fe-Ta system. Computational studies predict superior intrinsic magnetic properties for an experimentally not observed Fe_2Ta C36 Laves phase. This phase, however, occur in the Co-Ta system, which suggests the possibility of the existence of a stable compound along the $(Co_{1-x}Fe_x)_2Ta$ path. Following this route, we computationally predict a stable C36 Laves phase with improved intrinsic magnetic properties for large Fe content, and successfully synthesize it experimentally. This approach is general and can be applied to identify a synthesis path for a predicted material with desired properties.

MA 7.3 Mon 10:00 EB 407

Data-Mining Search for Rare-Earth-Free Permanent Magnets Among Predicted Crystal Structures — •Alena Vishina, Olle Eriksson, and Heike C. Herper — Department of Physics and Astronomy, Uppsala University, Sweden

Magnetic materials for energy applications (e.g. electric motors and wind turbines) is a boosting area of research, as many compounds used nowadays are based on undesirable expensive and environmentally-challenging rare earth (RE) elements. At the same time, with the increasing power of supercomputers and recent developments in machine-learning, new stable and metastable materials are being predicted that have never been synthesized before. The databases of such materials are an open field for data-mining searches for specific material properties.

One of the aforementioned databases [1] was used as an input for our recent investigation [2]. Filtering through around a million of compounds, we were searching for stable and meta-stable (likely to be synthesizable) materials with high magnetization, large uniaxial magnetocrystalline anisotropy, and high Curie temperature. The promising candidates were also tested for dynamic stability. Four systems were found that should be further explored as the candidates novel RE-free PMs - Ta3ZnFe8, AlFe2, Co3Ni2, and Fe3Ge.

Ref. 1. J. Schmidt et al, Materials Cloud archive 2022.126 (2022) 2. A. Vishina et al, Acta Materialia, 261, 119348 (2023)

MA 7.4 Mon 10:15 EB 407

Nano-composites for high performance Nd-Fe-B permanent magnets — •Lukas Schäfer[1], Imants Dirba[1], Fernando Maccari[1], Konstantin Skokov[1], Esmaeil Adabifiroozjaei[2], Leopoldo Molina-Luna[2], and Oliver Gutfleisch[1] — [1]Functional Materials, Materials Science, TU Darmstadt, Darmstadt, Germany — [2]Advanced Electron Microscopy, Materials Science, TU Darmstadt, Darmstadt, Germany

Permanent magnets (PM) based on Nd-Fe-B are important for modern electric motor and generator applications crucial to energy conversion. Especially due to the clean energy transition, which results in a higher demand for electric cars and wind turbines, the need for high performance PM is expected to drastically increase in the coming years. In order to improve the magnetic performance and, at the same time, reduce the content of critical rare earth, the design of nanocomposite microstructures consisting of the hard magnetic and soft magnetic phases is a promising approach. Textured "exchange-spring magnets" could, in theory, surpass the theoretical limit of today s commercial Nd-Fe-B magnets, yet despite three decades of research, bulk, textured nanocomposites with enhanced performance have not been realized yet. In this talk, a novel top-down approach based on the formation of a metastable phase in the Nd-Fe-B system by rapid solidification is presented. Microstructural and magnetic investigations will demonstrate the unique thermal decomposition of this phase into the hard magnetic $Nd_2Fe_{14}B$ phase and soft magnetic nano-precipitates of α-Fe, leading to an enhancement of the remanence.

MA 7.5 Mon 10:30 EB 407

Strong and ductile high temperature soft magnets through Widmanstätten precipitates — •Liuliu Han[1], Dierk Raabe[1], Oliver Gutfleisch[2], Fernando Maccari[2], Ivan Soldatov[3], and Rudolf Schäfer[3] — [1]Max-Planck-Institut für Eisenforschung, Max-Planck-Straße 1, 40237 Düsseldorf, Germany — [2]Department of Material Science, Technical University of Darmstadt, 64287 Darmstadt, Germany — [3]IFW Dresden, Institute for Metallic Materials, Helmholtzstr. 20, 01069 Dresden, Germany

Fast growth of sustainable energy production requires massive electrification of transport, industry and households, with electrical motors as key components. These need soft magnets with high saturation magnetization, mechanical strength, and thermal stability to operate efficiently and safely. Reconciling these properties in one material is challenging because thermally-stable microstructures for strength increase conflict with magnetic performance. Here, we present a material concept that combines thermal stability, soft magnetic response, and high mechanical strength. The strong and ductile soft ferromagnet is realized as a multicomponent alloy in which precipitates with a large aspect ratio form a Widmanstätten pattern. The material shows excellent magnetic and mechanical properties at high temperatures while the reference alloy with identical composition devoid of precipitates significantly loses its magnetization and strength at identical temperatures. The work provides a new avenue to develop soft magnets for high-temperature applications, enabling efficient use of sustainable electrical energy under harsh operating conditions.

MA 7.6 Mon 10:45 EB 407

Shape-dependent magnetic study of hematite nanospindles — •Juri Kopp[1], Joachim Landers[1], Soma Salamon[1], Gerald Richwien[2], Benoît Rhein[2], Annette Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute for Physical Chemistry, University of Cologne

Hematite nanospindles can be synthesized relatively easily in various aspect ratios and can be incorporated in aqueous solutions. When considering hematite-based ferrofluids, the question arises to what extent the degree of particle elongation influences the orientation behavior and mobility of nanospindles. For this purpose, hematite nanospindles with different aspect ratios in a 70 wt% glycerol-water mixture were investigated by magnetic field dependent Mössbauer spectroscopy, as well as magnetometry. As expected, the field-dependent Mössbauer experiments showed that the more elongated particles (aspect ratio of 3.7 and 5.2) were easier to align in the field due to the greater magnetic moment compared to the sample with a ratio of 2.5. Surprisingly the reference powder measurements for the sample with the aspect ratio of 1.0 showed a relatively sharp Morin-transition, in contrast to the rest of the other samples of higher aspect ratio, where no such transition occurred over the entire temperature range. Based on these results, we aim for the incorporation of the nanospindles into liquid crystalline matrices and to investigate anisotropic diffusion in ferronematic phases. We gratefully acknowledge funding by the DFG through LA5175/1-1.

15 min. break

MA 7.7 Mon 11:15 EB 407

Simulation of Interaction and Self-assembly of Magnetically Decorated Particles — •Maximilian Neumann, Sibylle Gemming, Oliver G. Schmidt, Daniil Karnaushenko, and Aaron Steinhäusser — TU Chemnitz, Chemnitz, Germany

The self-assembly of particles of modest complexity into elaborate structures is a governing principle in nature. In particular magnetic particles allow for a highly tunable interaction between them combined with manipulation through external sources (e.g. magnetic fields). By decorating cylindrical particles with permanent magnets in specific patterns along their edges we create distinct species of particles. These magnets are facing perpendicular to the base either in or out of the surface, resulting in a mix of attractive and repulsive interactions between individual magnets of different particles depending on proximity. In this way we facilitate the framework for self-assembly while introducing selectivity between species and different particle arrangements. We show different simulations of assembly schemes with a focus on finding parameters and pattern-groups that create strong attraction and high selectivity for matching patterns and set relative orientation while minimizing interaction across pairs.

MA 7.8 Mon 11:30 EB 407

Controlled transport of 3D anisotropic brick-shaped particles using dynamic magnetic field landscapes for Lab-on-Chip (LOC) applications — •Jonas Bugase, Christian Janzen, Arne Vereijken, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, 34132 Kassel

The controlled interaction of magnetic colloids amongst themselves and with surfaces in the presence of magnetic fields proves to be a valuable tool for studying and manipulating complex biological systems in microfluidic devices [1]. We present a remote-controlled transport mechanism for 3D elongated bricked-shaped magnetic particles, fabricated using two-photon polymerization (2PP) lithography. These particles are thoroughly characterized in terms of their sizes and magnetic properties. The magnetic moment of the polymer brick particles is fixed along the lateral axis by sputtering a magnetic Exchange Bias (EB) thin film system on its surface. The transport occurs within a periodic stray field landscape, artificially created by opposing domain stripe through ion bombardment induced magnetic patterning (IBMP) [2]. We discuss the influence of particle geometry and size in relation to the periodicity of the underlying domain pattern on the transport behavior. This transport mechanism is promising for the detection of biomolecules in Lab-on-Chip devices [3].

[1] Afsaneh *et al.* (2022), Talanta Open, (5): 100092.
[2] Ehresmann *et al.* (2015), Sensors, (15): 28854.
[3] Lowensohn *et al.* (2020), Langmuir, (36): 7100.

MA 7.9 Mon 11:45 EB 407

Application of white light interferometry for the absolute equilibrium height quantification of magnetic microbeads captured by tailored magnetic stray fields above a topographically flat surface — •Yahya Shubbak[1], André Stelter[2], Nikolai Weidt[1], Marco Künne[2], Rico Huhnstock[1], Peter Lehmann[2], and Arno Ehresmann[1] — [1]Institute of Physics & Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, D-34132 Kassel — [2]Institute of Measurement Technology, University of Kassel, D-34121 Kassel

Precise control of magnetic micro- and nanoparticles (MPs) in microfluidic environments allows for novel investigations in biomolecular analyte detection and interactions [1]. Utilizing static magnetic field landscapes from a magnetically patterned substrate, combined with external magnetic field pulses, facilitates translatory motion control of MPs at the micro-scale [2]. The close-to-substrate motion of MPs is sensitive to liquid-mediated particle-substrate interactions [3]. Monitoring changes in these interactions by measuring the equilibrium height of MPs above the substrate surface offers a promising approach for sensitive analyte detection. As a crucial step, we introduce white light interferometry to quantitatively measure the absolute distance between MPs and the underlying magnetic substrate. [1]Lim et al., *J. Phys. D: Appl. Phys.* **50**, 33002 (2017) [2]Holzinger et al., *Appl. Phys. Lett.* **100**, 153504 (2012) [3]Huhnstock et al., *Sci Rep* **12**, 20890 (2022)

MA 7.10 Mon 12:00 EB 407

Studying the influence of magnetic stripe domain size on the magnetophoretic transport of superparamagnetic beads for their controlled spatial fractionation — •Rico Huhnstock[1], Lukas Paetzold[1], Piotr Kuświk[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Institute of Molecular Physics, Polish Academy of Sciences, M. Smoluchowskiego 17, Poznań 60-179, Poland

Directed transport of magnetic particles for Lab-on-a-chip applications can be realized by superposing periodic magnetic stray field landscapes, emerging from tailored magnetic domain patterns, with external time-dependent magnetic fields [1]. A transition from a linear (phase-locked) to a non-linear (phase-slipping) motion behavior is typically observed for a critical frequency of the external field [2]. This critical frequency is a function of particle and domain pattern characteristics. Studying the latter influence is the scope of this work: We fabricated magnetic stripe domains of gradually increasing width within the same substrate and explored the motion dynamics of laterally transported superparamagnetic beads on top using an optical microscope. As a result, we observed position-dependent critical frequencies, which we will highlight to be beneficial for the spatial fractionation of beads with different magnetophoretic mobilities.

[1] Holzinger *et al.* (2015), ACS Nano, 9(7):7323.
[2] Yellen *et al.* (2007), Lab on a Chip, 7(12):1681.

MA 7.11 Mon 12:15 EB 407

Dynamic magnetic responses inside Magnetite nanoparticle chains detected by Scanning Transmission X-Ray Microscopy Ferromagnetic Resonance — Thomas Feggeler[1,2], Johanna Lill[1], Damian Günzing[1], Ralf Meckenstock[1], Detlef Spoddig[1], Sebastian Wintz[3], Markus Weigand[3], Benjamin Zingsem[1], Heiko Wende[1], Michael Farle[1], Hendrik Ohldag[2], and •Katharina Ollefs[1] — [1]Faculty of Physics and CENIDE, Duisburg, Germany — [2]Advanced Light Source, LBNL, Berkeley, United States of America — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Magnonic excitation of a nanoparticle chain of Magnetite particles (diameter of about 50 nm) embedded in a bacterium Magnetospirillum Magnetotacticum is measured using Scanning Transmission X-Ray Microscopy detected Ferromagnetic Resonance (TR-STXM) [1]. TR-STXM-FMR features the element specific detection of magnetization dynamics with a spatial resolution < 50 nm and a time resolution in the ps regime. A resonant response of the segments of the nanoparticle chain is identified and confirmed by micromagnetic simulations. The manipulation of the external applied magnetic field further allows to selectively excite different segments inside the nanoparticle chains demonstrating the feasibility of magnonic logic devices [2]. We acknowledge funding from DFG via project OL513/1-1, 321560838 and CRC TRR HoMMage.

[1] Th. Feggeler, et al., Phys. Rev. Res. 3, 033036 (2021).
[2] Th. Feggeler et al. New J. Phys. 25 043010 (2023).

MA 7.12 Mon 12:30 EB 407

Frequency mixing magnetic detection for characterization of SPIONs — •Ali Mohammad Pourshahidi, Andreas Offenhäusser, and Hans-Joachim Krause — Institute of Biological Information Processing, Bioelectronics (IBI-3), Forschungszentrum Jülich, Germany

The research on superparamagnetic iron oxide nanoparticles (SPIONs) explores their magnetic properties for bio-sensing and diagnostics. Frequency Mixing Magnetic Detection (FMMD) exploits SPIONs' nonlinear magnetization under dual-frequency magnetic excitation fields (a low-frequency field f_2 and a high-frequency field f_1). As a result, mixing harmonics in form of $f_1 + n \cdot f_2$ are generated that reveal insights into SPION behavior [1]. FMMD has shown significant potential in biosensing for point-of-care monitoring, offering a portable and a handheld solution [2]. Integration of a static offset magnetic field enables the detection of both even and odd harmonics. This enhancement broadens the diagnostic applications to include multiplex detection and characterization of SPION core size [3,4]. These advancements underscore FMMD's role as a tool, for better understanding of magnetic nanoparticle behavior, which is vital for advancing magnetic bio-sensing technologies. This presentation aims to highlight FMMD's applications in multiplex detection and core size analysis of SPIONs.

1. H.-J. Krause et al. JMMM 311(2007) 436 2. S. Achtsnicht et al. PLOS ONE 14 (2019) e0219356 3. A. M. Pourshahidi et al. Sensors 21(2021) 5859 4. A. M. Pourshahidi et al., JMMM 563 (2022) 169969

MA 8: INNOMAG e.V. Prizes 2024 (Diplom-/Master and Ph.D. Thesis)

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Dissertationspreis und einen Diplom-/Masterpreis ausgeschrieben, welche auf der Tagung der DPG 2024 in Berlin vergeben werden. Ziel der Preise ist die Anerkennung herausragender Forschung im Rahmen einer Diplom-/Masterarbeit beziehungsweise einer Promotion und deren exzellente Vermittlung in Wort und Schrift. Im Rahmen dieser Sitzung tragen die besten der für ihre an der Hochschule eines Mitgliedslands der European Physical Society durchgeführten Diplom-/Masterarbeit beziehungsweise Dissertation Nominierten vor. Im direkten Anschluss entscheidet das Preiskomitee über den Gewinner bzw. die Gewinnerin des INNOMAG e.V. Diplom/Master-Preises und des Dissertationspreises 2024. Talks will be given in English!

Time: Monday 15:00–18:25 Location: H 1058

MA 8.1 Mon 15:00 H 1058

Breakdown of Chiral Edge Modes in Topological Magnon Insulators — •Jonas Habel — Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany

Topological magnon insulators (TMI) are ordered magnets supporting chiral edge magnon excitations. These edge states are envisioned to serve as topologically protected information channels in low-loss magnonic devices. The standard description of TMI is based on linear spin-wave theory (LSWT), which approximates magnons as free noninteracting particles. However, magnon excitations of TMI are genuinely interacting even at zero temperature, calling into question descriptions based on LSWT alone. Here we perform a detailed nonlinear spin-wave analysis to investigate the stability of chiral edge magnons. For the first time, we provide direct theoretical evidence that the chiral edge states in topological magnon insulators decay. Our results highlight a challenge for the realization of novel spintronic devices based on topologically protected edge transport.

MA 8.2 Mon 15:20 H 1058

Dynamics of magnon gases in microscopic temperature landscapes — •Franziska Kühn[1], Matthias R. Schweizer[1], Georg von Freymann[1,2], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Fraunhofer Institute for Industrial Mathematics ITWM, Fraunhofer Platz 1, 67663 Kaiserslautern, Germany

This work is focused on the behavior of a thermally generated magnon gas in artificial magnetization landscapes on the micrometer scale. A unique setup was created by combining microfocused Brillouin light scattering spectroscopy with a heating laser, which imprints two-dimensional temperature landscapes onto the yttrium-iron garnet film sample by phase-based wavefront modulation. The temperature change, regulated by the power of the optical intensity patterns, influences the saturation magnetization and shifts the magnon dispersion relation. It was demonstrated with both measurements and simulations, that in addition to the magnetization variations, it is necessary to consider the connected variations of the demagnetization field. The local temperature-dependent demagnetization field influences the dispersion relation in the opposite direction and affects different magnon modes diversely, leading to strong frequency shifts. This effect creates a powerful tool for the manipulation of magnon Bose-Einstein condensates as well as for the directional control of magnon supercurrents. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-TRR 173/2-268565370 Spin+X (Project B04)

MA 8.3 Mon 15:40 H 1058

Optimized hyperthermia approach using Fe3O4/SiO2/Ni multishell nanoellipsoids — •Inci Nur Sahin[1], Marina Spasova[1], Michael Farle[1], Veronica Salgueirino[2], and Ecem Tiryaki[2] — [1]University Duisburg-Essen, Duisburg, Germany — [2]University of Vigo, Vigo, Spain

The use of approximately 20nm magnetite nanoparticles (NPs) for inductive heating has proven effective in cancer treatment, inducing necrotic cell death at temperatures above 43°C. Operating in the superparamagnetic state, these NPs don't exhibit remanent magnetization and stray fields, averting agglomeration and potential blood vessel clogging. Since foreign bodies below 50nm are deposited in the kidneys instead of in the tumour, larger diameters are desirable. However, magnetite particles that exceed the 20nm limit enter the ferromagnetic state with a noticeable demagnetizing field. This inevitably leads to the formation of clusters and poses a risk to the blood vessels. For this reason, magnetite/silica/nickel multi-shell ellipsoids were produced with the aim of compensating the stray fields of ferromagnetic NP. This is to be achieved by extinguishing the stray field of the core and the outer shells. Through a wet chemical process, 545nm long and 165nm wide Fe3O4/SiO2 NPs with a 10% standard deviation were prepared and coated with a 50nm thick nickel shell. Comparing the Nickel-sheathed and non-Nickel-sheathed NPs, it was found that the Nickel-sheathed NPs indeed exhibited a reduced remanence, provided three times the heating power 180 W/g during induction heating, and provided seven times the temperature increase $\Delta T = 20°C$.

15 min. break

MA 8.4 Mon 16:15 H 1058

Spintronic terahertz emission: insights and applications — •Oliver Gueckstock — Freie Universität Berlin

To extend current charge-based electronics by new features and functionalities, the electron spin, as a new degree of freedom, is likely to play a major role in future information technology. Devices using spintronics need to be competitive with other information carriers and, therefore, it is required to push the bandwidth of the elementary spintronic operations to the terahertz (THz) frequency range. To study ultrafast spin transport in prototypical magnetic-non-magnetic (F|N) bilayers, we excite them with femtosecond laser pulses. Following absorption of the pulse, a spin current in F is launched and converted into a transverse charge current in N and/or F, giving rise to the emission of a THz electromagnetic pulse. Using this approach, along with an analysis based on symmetry arguments and modeling, this thesis answers the following central open questions: Is ultrafast spin transport mediated by magnons as universal as indicated by previous modelling? What impact does the frequently neglected F/N interface between F and N have on the ultrafast spin-to-charge current conversion? How can we exploit spintronic features for new functionalities of spintronic THz emitters, which are also potentially interesting for space applications? By studying spin current dynamics on their natural timescale, one may find new interesting effects or push existing concepts to THz frequencies, which might advance future spintronic applications to work at higher clock rates.

MA 8.5 Mon 16:40 H 1058

Spin waves in curved magnetic shells — •Lukas Körber — HZDR, Dresden, Germany — TU Dresden, Germany

Exploring 3D systems has attracted several research fields, including the study of ferromagnets and superconductors. Given the underlying order parameter and interactions, twisting and bending flat into curved shells leads to emerging effects when the bending radius approaches the system's internal length scales. Curvature-induced anisotropies and magnetochiral interactions have been widely studied in ferromagnetic systems, uncovering the stabilization of solitons, pinning of domain walls, or suppression of the Walker breakdown.

The impact of curvature and geometry on low-energy magnetization dynamics (the propagation of spin waves) manifests in several aspects. For example, curvature can modify dynamic magnetic charges. As a result, magneto-chiral symmetry breaking of magnetostatic origin can lead to asymmetric spin-wave dispersion, nonreciprocal spatial mode profiles and strongly modify nonlinear magnetization dynamics. Moreover, a nontrivial topology of three-dimensional magnetic specimens can induce a Berry phase of spin waves or impose selection rules on the dynamics of magnetic textures. Furthermore, achiral symmetry breaking, induced, e.g., by lowering rotational symmetries, can lead to symmetry-governed doublet splitting. Here, we explore several of the aforementioned geometrical effects on magnetization dynamics and present the development of noval numerical techniques to study spin waves in curved magnetic shells efficiently.

MA 8.6 Mon 17:05 H 1058

Antiferromagnetic Insulatronics: Control and Manipulation of Magnetic Domains — •Hendrik Meer — Institute of Physics, Johannes Gutenberg-University Mainz

The control of the spin structure is key for the development of future antiferromagnetic spintronic devices. Here, we explore how the antiferromagnetic domains of insulating NiO and CoO thin films can be manipulated. We use synchrotron and lab-based imaging to investigate three key tools to control the antiferromagnetic order: First, we apply electric currents through an adjacent heavy metal layer and study different device geometries to determine the underlying switching mechanism [1]. Second, we investigate the effect of the patterning shape on the antiferromagnetic ground state [2]. Third, we explore a non-contact writing scheme of the antiferromagnetic ordering via irradiation with laser pulses [3]. By revealing several writing mechanisms for the antiferromagnetic order, we expand the toolbox of antiferromagnetic insulatronics [4].

[1] H. Meer et al., Nano Lett. 21, 114 (2021).
[2] H. Meer et al., Phys. Rev. B 106, 094430 (2022).
[3] H. Meer et al., Adv. Funct. Mater. 2213536 (2023).
[4] H. Meer et al., Appl. Phys. Lett. 122, 080502 (2023).

MA 8.7 Mon 17:30 H 1058

Exploring ultrafast dynamics of electrons in heavy-fermion materials by THz time-domain spectroscopy — •Chia-Jung Yang and Manfred Fiebig — Department of Materials, ETH Zurich, Switzerland

The development of novel states of matter is a significant aspect of modern physics, with quantum phase transitions (QPT) playing a crucial role. These transitions are dominated by quantum fluctuations of magnetic and electronic degrees, giving rise to new behavior emerging near the quantum-critical point. Heavy-fermion materials, which exhibit strong coupling between magnetic and electronic properties, serve as an ideal platform for exploring these phenomena. This work utilizes terahertz time-domain spectroscopy (THz-TDS) to investigate the ultrafast electronic dynamics across QPTs in such materials. THz-TDS, effective in probing low-energy excitations, illuminates the dynamics of quasiparticles and provides direct access to information that was otherwise not accessible before [1]. In prototypical heavy-fermion materials, we have thus discovered novel types of quantum-matter dynamics. Specifically, in $YbRh_2Si_2$, we observed the first example of critical slowing down in a fermionic system close to a QPT [2]. In $CeCu_{6-x}Au_x$, we distinguished two different correlated contributions to the optical conductivity [3] and identified lattice coherence in the form of heavy-fermion formation from optical coherence in the form of superradiance.

[1] Nat. Rev. Mater **8**, 518 (2023). [2] Nat. Phys. **19**, 1605 (2023). [3] Phys. Rev. Research **2**, 033296 (2020)

30 min. discussion break and bestowal of INNOMAG e.V. Diplom-/Master Prize and Ph.D. Thesis Prize

MA 9: Ultrafast Magnetization Effects II

Time: Monday 15:00–18:30 Location: H 2013

Invited Talk MA 9.1 Mon 15:00 H 2013

Optical control of 4f orbital state in rare-earth metals — •N. Thielemann-Kühn[1], T. Amrhein[1], W. Bronsch[2], S. Jana[3], N. Pontius[3], R. Y. Engel[4], P. S. Miedema[4], D. Legut[5], K. Carva[6], U. Atxitia[1], B. E. van Kuiken[7], M. Teichmann[7], R. E. Carley[7], L. Mercadier[7], A. Yaroslavtsev[7], G. Mercurio[7], L. Le Guyader[7], N. Agarwal[7], R. Gort[7], A. Scherz[7], S. Dziarzhytski[4], G. Brenner[4], F. Pressacco[4], R.-P. Wang[4,10], J. O. Schunck[4,10], M. Sinha[4], M. Beye[4], G. S. Chiuzbăian[9], P.. Oppeneer[8], M. Weinelt[1], and C. Schüssler-Langeheine[3] — [1]Freie Universität Berlin — [2]Elettra-Sincrotrone Trieste — [3]Helmholtz-Zentrum Berlin — [4]Deutsches Elektronen-Synchrotron — [5]IT4Innovations & Nanotechnology Centre — [6]Charles University — [7]European XFEL — [8]Uppsala University — [9]Sorbonne Université — [10]Universität Hamburg

Rare-earth 4f metals play a key role in materials which allow all-optical switching and their large spin-orbit coupling can result in strong magneto-crystalline anisotropy (MCA) - a property highly relevant for stable magnetic information storage. In time-resolved X-ray absorption (XAS) and Resonant inelastic X-ray scattering (RIXS) studies on different 4f-metals, we found that 5d-4f inelastic electron-electron scattering leads to selective excitation in the 4f shell, which change the angular momentum J. As a consequence, the MCA and thus coupling of the 4f-spin system to its environment is manipulated on fs-timescales. In the case of Dy we observed ferro- and antiferromagnetic dynamics to be strongly affected by the altered electronic state.

MA 9.2 Mon 15:30 H 2013

Ultrafast demagnetization dynamics in Fe studied by tr-ARPES — •Xinwei Zheng, Christian Strüber, and Martin Weinelt — Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin

We investigate the ultrafast magnetization dynamics of Fe(110) on W(110) by time- and angle-resolved photoemission spectroscopy (tr-ARPES) with an IR pump pulse and a high-order harmonic XUV probe pulse. After laser excitation, transient changes to the band structure with tr-ARPES are observed. In contrast to a small reduction of the exchange splitting by only 3%, the magnetic linear dichroism signal calculated from the asymmetry between spectra for two opposite in-plane magnetization directions drops by 60% within 150 fs. This result proves that spin-mixing dominates the ultrafast demagnetization dynamics in Fe [1]. Moreover, we measure a stronger reduction of the asymmetry in the minority spin band close below the Fermi level compared to that in the majority spin band at a binding energy of 0.3 eV. This indicates that the spin system in Fe is out of equilibrium for about 1-2 ps after laser excitation [2]. The pump-fluence dependence of the MLD signal and the electronic temperature implies that a significant amount of energy is transferred into the spin system within 150 fs, leading to spin excitations particularly within the minority spin band.

[1] E. Carpene *et al.*, Phys. Rev. B. **78**, 174422 (2008)
[2] R. Gort *et al.*, Phys. Rev. Lett. **121**, 087206 (2018)

MA 9.3 Mon 15:45 H 2013

Unraveling light-driven spin transfer and hot carrier dynamics by EUV magneto-optical spectroscopy — •G. S. Matthijs Jansen[1], Christina Möller[1], Henrike Probst[1], John Kay Dewhurst[2], Marcel Reutzel[1], Sangeeta Sharma[2], Daniel Steil[1], and Stefan Mathias[1] — [1]I. Physikalisches Institut, Georg-

August-Universität Göttingen — [2]Max-Born-Institute for Non-linear Optics and Short Pulse Spectroscopy, Max-Born Strasse 2A, 12489 Berlin, Germany

In recent years, extreme ultraviolet magneto-optical spectroscopy has helped to identify a number of unique ultrafast magnetization processes, including optical inter-site spin transfer (OISTR) and delayed demagnetization in Fe-Ni alloys. However, the interpretation in terms of the element-resolved magnetic moment in non-equilibrium is not always straightforward, as we have recently shown for transverse magneto-optical Kerr spectroscopy of Ni and Fe-Ni thin films [1, 2]. To overcome this issue, we demonstrate that an angle-resolved analysis enables complete access to the magneto-optical response function, and moreover enables a quantitative comparison to ab-initio theoretical calculations. Through such an analysis, we are able to verify the existence of OISTR in Fe-Ni alloys and furthermore shine light on the intimate connection between OISTR and delayed demagnetization [2].

[1] H. Probst et al., arXiv preprint arXiv:2306.02783 (2023)
[2] C. Möller et al., arXiv preprint arXiv:2306.02793 (2023)

MA 9.4 Mon 16:00 H 2013

Phonon mediated spin-spin interaction — •Daniel Schick[1], Markus Weissenhofer[2,3], Akashdeep Kamra[4], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, Konstanz, Germany — [2]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [3]Department of Physics, Freie Universität Berlin, Berlin, Germany — [4]IFIMAC - Condensed Matter Physics Center, Universidad Autónoma de Madrid, Madrid, Spain

The transfer and control of angular momentum is a key aspect for spintronic applications. Recently, it has been realized, that even the lattice can contribute to the exchange of angular momentum via chiral phonons. To simulate spin lattice coupling, we developed a numerical method, which is able to conserve the total angular momentum, allowing us to precisely track changes thereof in transfers between the spin and lattice system [1, 2]. In our simulations, magnetic spins can excite chiral phonons, which themselves are able to elicit a response of other spins, creating an effective spin-spin coupling via phonons. We discuss this interaction by driving spins to investigate the processes involved and determine the importance of the chirality of the phonons. In finite-temperature simulations, we investigate the thermodynamic implications of this interaction.

[1] S. Mankovsky et. al, Phys. Rev. Lett. **129**, 067202, (2022)
[2] M. Weißenhofer et. al, Phys. Rev. B **108**, L060404, (2023)

MA 9.5 Mon 16:15 H 2013

Non-Hermitian phase transition in optically-driven ferromagnetic semiconductors — •J. Li[1], M. Matsubara[2], K. Kliemt[3], N. Kaya[3], I. Reiser[3], M. Turaev[4], C. Krellner[3], S. Pal[5], J. Kroha[4], and M. Fiebig[1] — [1]ETH Zurich, Switzerland — [2]Tohoku Uni., Japan — [3]Goethe Uni. Frankfurt, Germany — [4]Bonn Uni., Germany — [5]NISER Bhubaneshwar, India

Phase transition in thermodynamic equilibrium is a heavily studied topic. Recently, however, non-equilibrium phase transitions have been drawing attention. Such transitions occur typically in open quantum systems dissipatively coupled to the environment and/or driven by external fields. As a result, the Hamiltonian eigenvalues can be complex-valued, which is why these transitions are referred to as non-Hermitian phase transition (NHPT). While most of the previous works studied bosonic quantum systems, we report our observation of a NHPT in a fermionic quantum system, i.e., the ferromagnetic semiconductor EuO. EuO has a Curie temperature (T_C) of 69 K. In our study, it is driven out of equilibrium by a 120 fs optical pump pulse at 1.55 eV. We probe the relaxation dynamics by measuring the pump-induced reflectivity change using another time-delayed 120 fs optical probe pulse at 1.31 eV. Below T_C, we find a clear signature of bi-exponential decay of the pump-induced reflectivity change, which becomes a damped, oscillatory behavior above T_C, indicating the appearance of complex eigenvalues of the optical response function. Our results reveal that the non-equilibrium situation triggers a NHPT in EuO that is marked by an exceptional point where two eigenvalues coalesce.

MA 9.6 Mon 16:30 H 2013

Nucleation and domain growth during the laser-induced metamagnetic phase transition in FeRh identified by UXRD — •Maximilian Mattern[1], Steffen Zeuschner[1], Jon Ander Arregi[2], Vojtěch Uhlíř[2], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Germany — [2]CEITEC BUT, Brno University of Technology, Czech Republic — [3]Helmholtz-Zentrum Berlin, Germany

We use time-resolved x-ray diffraction (UXRD) to study the laser-induced first-order antiferromagnetic (AFM) to ferromagnetic (FM) phase transition in FeRh that is accompanied by a gigantic expansion (≈ 0.6%). The laser-induced rise of this expansion accesses the transient FM volume fraction independent of the orientation of the magnetic moment. By comparing two samples with thicknesses below and above the optical penetration depth, we disentangle optically induced nucleation on an intrinsic 8 ps timescale in the near-surface region from the growth of the nucleated FM domains into the depth of the thick inhomogeneously excited FeRh film by slow heat diffusion.

We observe this 8 ps nucleation timescale even in the absence of a transient hot Fermi-distribution of the electrons, when we increase the pump pulse duration up to 10.5 ps. This indicates that hot electrons are not required for driving the phase transition on its intrinsic timescale. Instead, we identify a non-linearity in the laser-induced expansion due to the treshold behaviour of the first-order phase transition, that only starts when the energy successively deposited by the ps-pump pulse overcomes the local critical treshold.

15 min. break

MA 9.7 Mon 17:00 H 2013

Ultrafast electron scattering in a ferromagnetic two-sublattice system — •Ariyan Tavakoli, Kai Leckron, and Hans Christian Schneider — Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

We investigate an exchange coupled two-sublattice system as a model for a ferromagnetic alloy, as introduced in [1]. In addition to the exchange coupling between an itinerant and a localized spin system, and the electron-phonon scattering in the itinerant system we also include the electron-electron Coulomb interaction in the itinerant system. We study numerically the heat-induced ultrafast magnetization dynamics due to electron-electron, electron-phonon, Elliott-Yafet spin-flip and exchange scattering and discuss different scenarios for the demagnetization and relaxation dynamics of the sublattice. Our results show the impact of electron-electron scattering for the spin dynamics on ultrashort timescales.

[1] K. Leckron, A. Baral and H. C. Schneider, "Exchange scattering on ultrafast timescales in a ferromagnetic two-sublattice system", Appl. Phys. Lett. 120, 102407 (2022).

MA 9.8 Mon 17:15 H 2013

Time-resolved resonant magnetic small-angle scattering with a laser-driven soft-X-ray plasma source — •Leonid Lunin[1], Niklas Schneider[1], Konstanze Korell[1], Martin Borchert[1], Michael Schneider[1], Johannes Tümmler[1], Stefan Eisebitt[1,2], Bastian Pfau[1], and Daniel Schick[1] — [1]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany — [2]Institut für Optik & Atomare Physik, TU Berlin, Germany

Resonant soft-X-ray scattering methods provide unique possibilities to study nanometer-scale magnetization dynamics with element selectivity and on ultrafast timescales when employing ultrashort pulsed X-ray sources. Based on a laser-driven plasma X-ray source, we have developed a novel instrument to carry out time-resolved magnetic small-angle X-ray scattering (SAXS) experiments in the soft-X-ray range between 500 and 1500 eV with sub-10 ps temporal resolution. In this contribution, we show time and element-resolved magnetic SAXS results of a photoexcited GdFe multilayer sample. The 2D scattering patterns collected contain information on the local magnetization, periodicity, and distribution of the magnetic maze domains in GdFe. The development of an online processing software for a hybrid-pixel detector enables us to drastically enhance the signal-to-noise ratio of the time-resolved data and reduce overall dead-times of the setup. Due to the flexibility of our laboratory-scale setup, we can further vary the sample environment, e.g., by applying external magnetic fields as well as cryogenic temperatures, and observe significant differences in the ground-state-dependent dynamics of the magnetic domains.

MA 9.9 Mon 17:30 H 2013

Ballistic or Diffusive transport? Signature in Complex Kerr response of magnetized films — •Sanjay Ashok, Jonas Hoefer, Martin Stiehl, Martin Aeschlimann, Hans-Christian Schneider, Baerbel Rethfeld, and Benjamin Stadtmueller — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau

Transport mechanisms play an important role in ultrafast demagnetization. We calculate the influence of diffusive and ballistic transport on ultrafast magnetization dynamics in metallic magnets with varying film thicknesses [1]. We then simulate the probe-angle dependent Kerr-rotation and -ellipticity (CMOKE) dynamics [2, 3].

Our simulations reveal probe-angle dependence in the Kerr-ellipticity dynamics for the diffusive transport case. In contrast, no angle dependent signatures were found for the case when ballistic transport is predominant. No probe-angle dependence are found in the Kerr-rotation dynamics with either of the transport mechanisms.

Our theoretical predictions are compared with probe angle dependent CMOKE measurements on a 40 nm thick Nickel film. The angle dependence of the measured Kerr signals closely matches the simulated response with diffusive transport. Thus, we demonstrate the utility of probe-angle dependent CMOKE technique and, importantly, that the ballistic transport can be neglected in a 40nm thick Nickel film.

[1] Ashok et al. APL, 120 142402 (2022)
[2] Traeger et al. PSS, 131, 201 (1992)
[3] Kuch et al. Springer Surf. Sci. 57, (2015)

MA 9.10 Mon 17:45 H 2013

Influence of thermal disorder on ultrafast demagnetization — •Franziska Ziolkowski, Oliver Busch, Ingrid Mertig, and Jürgen Henk — Martin Luther University Halle-Wittenberg, Halle, Germany

Ultrafast demagnetization induced by ultrashort laser pulses in magnetic materials remains a topic of intense investigation. To explain the rapid quenching of magnetization various spin flip and spin transfer mechanisms are discussed in literature. With the theoretical framework EVOLVE [1] we investigate such ultrafast magnetization dynamics.

Our approach is based on a real-space tight-binding model and includes optical excitation as well as coupling to an external heat bath. The occupation matrix yields the system's observables and is evolved in time by the Lindblad equation. This approach allows to reveal and to tune the relevant underlying processes.

Our study examines the influence of thermal disorder within the magnetic configuration on ultrafast demagnetization. We determine the regime of influence, which is the pertinent parameter space for this effect. Furthermore a comparison is made between spin current generation and ultrafast demagnetization in homogeneous systems versus ferromagnetic-nonmagnetic heterostructures.

[1] Töpler *et al* 2021 *New J. Phys.* **23** 033042

MA 9.11 Mon 18:00 H 2013

Real-space imaging of ultrafast dynamics in nanoscale magnetic domains — •Hung-Tzu Chang[1], Sergey Zayko[1], Timo Schmidt[2], Murat Sivis[1,3], Manfred Albrecht[2], and Claus Ropers[1,3] — [1]Max Planck Institute for Multidisciplinary Sciences, 37077 Goettingen, Germany — [2]Experimental Physics IV, Institute for Physics, University of Augsburg, 86159 Augsburg, Germany — [3]IV Physical Institute, University of Goettingen, 37077 Goettingen, Germany

Direct visualization of photoinduced dynamics of nanoscale spin textures is crucial for understanding the mechanisms of ultrafast demagnetization and all-optical magnetic switching. Here, we image the real-space response of magnetic domains in optically excited Co-based magnetic thin films with circularly polarized femtosecond extreme ultraviolet pulses [1]. Our experiment provides direct observations of domain wall dynamics at picosecond timescales, as well as the photoinduced disappearance of small domains, which should further advance the understanding of spin dynamics in nanomaterials.

[1] Zayko et al. Nat. Commun. 12, 6337 (2021)

MA 9.12 Mon 18:15 H 2013

Exciton-driven phonon dynamics in a magnetic layered semiconductor CrI_3 — •Martin Pavelka, Vishal Shokeen, Ruslan Chulkov, Alexander Yaroslavtsev, Johanna Rogvall, David Muradas, Ulrich Noumbe, Mahmoud Abdel-Hafiez, Venkata Kamalakar Mutta, Oscar Grånäs, and Hermann Dürr — Uppsala University, Uppsala, Sweden

CrI_3 is a prototype of a new class of magnetic 2D materials displaying ferromagnetic order down to the monolayer limit [1]. Its optical and magneto-optical spectra feature several excitonic dd-transitions characterized by spin-polarized electron and hole pairs with evidence of strong coupling to optical phonons [2].

In this talk, we will describe the ultrafast optical and magneto-optical responses of CrI_3. Our two-colour femtosecond spectroscopy allows us to investigate the interplay of exchange interaction and electron-phonon coupling. Following the optical generation of excitons, we observe coherent oscillations in the time-domain. Fourier transformation of the spectra shows two coherent phonon modes, the A^1_{1g} and A^2_{1g} symmetries, at frequencies of 2.4 and 3.9 THz, respectively. Theoretical calculations show that both modes couple to the magnetic order, in agreement with our observations. This finding is contrary to the previous report [2]. The starting phase of these two impulsively excited modes indicates a magnetic contribution to their generation. We also explore the fluence dependence of these phenomena to assess the possible influence of neighbouring excitons.

[1] Nature 546, 270-273 (2017). [2] Nat Commun 13, 4473 (2022).

MA 10: Electron Theory of Magnetism and Correlations/Other Theory

Time: Monday 15:00–18:00 Location: EB 107

MA 10.1 Mon 15:00 EB 107

Broken-symmetry magnetic phases in two-dimensional triangulene crystals — João C. G. Henriques[1,2], Gonçalo Catarina[3], David Jacob[4], Alejandro Molina-Sánchez[5], •António T. Costa[1], and Joaquín Fernández-Rossier[1] — [1]International Iberian Nanotechnology Laboratory, Braga, Portugal — [2]Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [3]Swiss Federal Laboratories for Materials Science and Technology, 8600 Dübendorf, Switzerland — [4]Universidad del País Vasco, San Sebastián, Spain — [5]University of Valencia, Valencia, Spain

We provide a theory of magnetic phases in 2D triangulene crystals, using both Hubbard model and density functional theory (DFT) calculations. We consider centrosymmetric, non-centrosymmetric and nitrogen-doped triangulene crystals. In the undoped cases, DFT and mean-field Hubbard model predict the emergence of broken-symmetry antiferromagnetic and ferrimagnetic phases. We also compute the spin wave spectrum of these crystals.The results are in excellent agreement with the predictions of a Heisenberg spin model derived from multi-configuration calculations for the unit cell.

For the N-doped case we show that the low energy excitations include strongly coupled spin and orbital degrees of freedom. The key ingredient is the existence of orbital degeneracy, which forces us to leave the benzenoid/half-filling scenario. We find a rich interplay between orbital and spin degrees of freedom that confirm the need to go beyond the spin-only paradigm.

MA 10.2 Mon 15:15 EB 107

Exploring Temperature-Dependent Magnetic Properties in NiO: A First Principles Study — •Ravi Kaushik[1,2], Ryota Ono[3], and Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genova 16163, Italy — [2]University of Genova. Genova, Italy — [3]National Institute for Materials Science, Ibaraki, Japan

Knowing the magnetic Hamiltonian parameters, such as Heisenberg exchange constants, is crucial for describing magnetic properties of materials. Such parameters can be efficiently calculated using Density Functional Theory, which operates at T=0. Magnetic materials exhibit a complex interplay between spin, orbital, and lattice degrees of freedom, and magnetic exchange interactions are influenced by thermally excited phonons. Here we develop a method to compute the change in exchange constants with temperature, and test it on a paradigm antiferromagnet, NiO. Our approach is based on a special displacement method, which should be modified to use two specific configurations with opposite displacements, to average out the exchange contribution, linear in phonon amplitude. The results enable the calculation of magnetic exchange constants and modelling of magnetic systems, at finite temperatures and set the stage for more intricate studies in systems with complex interdependencies.

MA 10.3 Mon 15:30 EB 107

Analysis of the topology of NiS2 based on magnetic topological quantum chemistry — •Mikel Iraola[1,2], Iñigo Robredo[1,3], Martina Sondini[4], Titus Neupert[4], and Maia Vergniory[1,3] — [1]Donostia International Physics Center, Donostia-San Sebastián, Spain — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung, Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]University of Zürich, Zürich, Switzerland

NiS2 exhibits a non-collinear antiferromagnetic ordering that preserves the translational symmetry of the paramagnetic structure. Furthermore, previous theoretical works have reported that spin-orbit coupling and strong electronic interactions might play an important role in the electronic properties of the compound. Recently, experimental analyses have reported evidences of surface transport, hinting at the potential existence of surface conducting states of topological origin. This rich phenomenology makes NiS2 an interesting testbed to explore the interplay between magnetism, electron interactions and topology. In this work, we combine ab initio simulations and symmetry-based arguments to investigate the bulk and surface electronic structures of NiS2 within the framework of magnetic topological quantum chemistry.

MA 10.4 Mon 15:45 EB 107

Electronic and magnetic structures of $AgCrX_2$ (X=S, Se, Te) through first-principles density functional theory — •Seo-Jin Kim[1], Gesa Siemann[2], Chiara Bigi[2], Phil King[2], Giovanni Vinai[3], Vincent Polewczyk[3], Haijing Zhang[1], Michael Baenitz[1], and Helge Rosner[1] — [1]MPI CPfS, Dresden, Germany — [2]SUPA, University of St. Andrews, St. Andrews, UK — [3]IOMCNR, Laboratorio TASC, Trieste, Italy

We present a comprehensive study of the electronic and magnetic structures of $AgCrX_2$ (X=S, Se, Te) using first-principles density functional theory. The dichalcogenide $AgCrX_2$ forms a layered triangular lattice akin to delafossite systems, but it lacks inversion symmetry. This absence contributes to unique properties, such as the spin-polarized surface state [1] and the unconventional anomalous Hall effect [2] in $AgCrSe_2$. Our previous experiments on $AgCrSe_2$ revealed a complex magnetic spin texture with a long cycloidal coupling in the plane and an anti-parallel coupling between layers below T_N=32K [3]. This investigation aims to analyze electronic structure variations resulting from different covalency introduced by substituting chalcogen atoms. Additionally, using hopping parameters extracted by the Wannier function approach, we explore the intricate interplay between crystal and magnetic structures across all compounds of the series.

[1] G.-R. Siemann et al., npj Quantum Mater. 8, 61 (2023). [2] S.-J. Kim et al., arXiv:2307.03541, Advanced Science (accepted; 2023). [3] M. Baenitz et al., Physical Review B, 104, 134410 (2021).

MA 10.5 Mon 16:00 EB 107

Instabilities towards weak ferromagnetism and spin spirals in the non-collinear anti-ferromagnet Mn_3Sn. — Lars Nordström[1], Anders Bergman[1], and •Ramon Cardias[2] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Instituto de Física, Universidade Federal Fluminense, 24210-346, Niterói RJ, Brazil

From accurate electronic structure calculations of the non-collinear antiferromagnet Mn_3Sn, the magnetic exchange interactions are obtained and used to study instabilities of the magnetic structure as well as to calculate the spectra of collective excitations. The initial antiferromagnetic structure with coplanar local magnetic moments rotated by 240° due to the frustration within the Kagome-like structure, is shown to be first unstable towards a magnetic structure with incomplete compensation of the antiferromagnetic moments, leading to a small ferromagnetic moment. In addition this structure in turn is further unstable towards a formation of an in-commensurate spiral. Both these instabilities are analysed and their origin is discussed in a more general context.

MA 10.6 Mon 16:15 EB 107

Two-particle self-consistent approach for broken symmetry phases — •Lorenzo Del Re — Max-Planck-Institute for Solid State Research, 70569 Stuttgart, Germany

Spontaneous symmetry breaking of interacting fermion systems constitutes a major challenge for many-body theory due to the proliferation of scattering channels once degenerate in the symmetric phase. One example is given by the ferro/antiferromagnetic broken symmetry phase (BSP) of the Hubbard model, where vertices in the spin-transverse and spin-longitudinal channels become independent with a consequent increase in the computational power for their calculation.

Here we generalize the formalism of the non-perturbative Two-Particle-Self-Consistent method (TPSC) to treat broken SU(2) magnetic phases of the Hubbard model. We show how in the BSP, the sum-rule enforcement of susceptibilities must be accompanied by a modified gap equation resulting in a renormalisation of the order parameter, vertex corrections and the preservation of the gap-less feature of the Goldstone modes.

We then apply the theory to the antiferromagnetic phase of the 3D-Hubbard model in the cubic lattice at half-filling. We compare our results of double occupancies and staggered magnetisation to the ones obtained using Diagrammatic Monte Carlo showing good quantitative agreement between the two methods.

We argue how vertex corrections play a central role in lowering the Higgs resonance with respect to the quasi-particle excitation gap in the spin-longitudinal susceptibility, yielding a well visible Higgs-mode.

15 min. break

MA 10.7 Mon 16:45 EB 107

Magneto structural correlations in the binary compound Cr_3Se_4 — •Helge Rosner, Seojin Kim, Yurii Prots, Marcus Schmidt, and Michael Baenitz — Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany

Cr_3Se_4 crystallises in a monoclinic lattice, structurally closely related to the rhombohedral chalcogenite delafossite-like systems $ACrX_2$ with A = Na, Cu, Ag and X = S, Se. In contrast to these intrinsically semiconducting materials with a nonmagnetic monovalent A site, in Cr_3Se_4 the distorted triangular $CrSe_2$ layers are separated by a formally trivalent and magnetic ion. Motivated by the reported exotic physical properties of the ternary $ACrX_2$ compounds, like multiferroic behaviour, unconventional magnetic ordering or anomalous Hall conductivity, we present here an ongoing joint experimental and theoretical study of the related binary material Cr_3Se_4. The metallic system undergoes an antiferromagnetic ordering at about 160 K which is strongly coupled to the crystal lattice. Density functional band structure calculations show that the conduction bands originate from strongly hybridised Cr-Se states with sizeable spin-orbit interaction. In a detailed comparison, we will highlight the similarities and differences between Cr_3Se_4 and the chalcogenite delafossites.

MA 10.8 Mon 17:00 EB 107

Paramagnons in $Na_xCa_{2-x}CuO_2Cl_2$ from a Quantum Cluster Approach using Matrix-Product States — •Abhiroop Lahiri[1], Sebastian Paeckel[2], Thomas Köhler[3], and Benjamin Lenz[1] — [1]IMPMC UMR-7590,CNRS, Sorbonne Université, Paris, France — [2]Ludwig-Maximilians-Universität München, Germany — [3]Uppsala Universitet, Uppsala, Sweden

In recent years, advances in the field of resonant inelastic x-ray scattering (RIXS) have rendered the measurement of paramagnons in doped cuprates feasible. In certain cases, the collective low-energy excitations seen in the RIXS map can be described to a good approximation by the dynamical spin structure factor. In this talk, we will show a comprehensive study of this quantity for a doped Hubbard-type model, tailored via ab initio simulations to the cuprate $Na_xCa_{2-x}CuO_2Cl_2$. In our calculations, we choose different quantum clusters and employ matrix-product states (MPS) to describe the cluster wave-function. This efficient way of representing the essential part of the Hilbert space allows us to treat cluster sizes within density matrix renormalization group that go beyond the scope of standard exact diagonalization solvers. In particular, our approach is based on a recently developed band-Lanczos method optimized for the use of MPS. We finally compare our results to the literature, in particular to cluster dynamical mean-field theory calculations and RIXS measurements of the material.

MA 10.9 Mon 17:15 EB 107

Modeling non-local Coulomb interaction in 2D Van der Waals materials using the DFT+$U+V$ method — •Wejdan Beida[1,2], Gustav Bihlmayer[1], Gregor Michalicek[1], Daniel Wortmann[1], Ersoy Sasioglu[3], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Physics Department, RWTH-Aachen University, 52062 Aachen, Germany — [3]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle (Saale), Germany

For bilayer graphene it was found the non-local Coulomb interaction, denoted as V, is crucial for the description of the electronic structure [1]. In this presentation, we extend the investigation to 2D van der Waals materials characterized by covalent bonds between magnetic $3d$-transition metal atoms and atoms possessing polarizable and delocalized p-electrons. To address this, we have theoretically formalized the incorporation of this interaction into a Hamiltonian model system and found renormalization of the magnetic interactions. Subsequently, we have implemented this theoretical framework into our FLEUR code [2], which is based on the Full-potential Linearized Augmented Plane Wave method. We comprehensively examined the impact of V on the electronic properties using the DFT+$U+V$ approach. V-values have been determined from microscopic theory on the level of constrained random phase approximation.

[1] Wehling, T. O., et al. Physical Review Letters 106.236805 (2011). [2]FLEUR: https//doi.org/10.5281/zenodo.7778444

MA 10.10 Mon 17:30 EB 107

Quantum kinetic equation and thermal conductivity tensor for bosons — •Léo Mangeolle[1,2,3], Lucile Savary[1,2], and Leon Balents[2] — [1]ENS de Lyon, CNRS, Laboratoire de Physique, 46 allée d'Italie, 69007 Lyon, France — [2]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106 — [3]Technical University of Munich, School of Natural Sciences, Physics Department, 85748 Garching, Germany

We obtain a systematic derivation of the semi-classical kinetic equation for neutral bosons from their full quantum kinetic equation. It incorporates the semi-classical topological dynamics of wavepackets in the form of geometric properties of the energy eigenstates, such as the Berry phases and curvatures, generalized to phase space. This makes it possible to treat inhomogeneous systems, including boundaries, textures, etc., in a compact and natural manner. We compute the associated observable quantities, such as energy and current densities, away from equilibrium. In particular, the thermal conductivity tensor, which describes the energy current induced by a temperature gradient, is exactly obtained. This provides a self-contained and exact derivation of the intrinsic thermal Hall effect of neutral bosons such as phonons and magnons, in agreement with Kubo formula results while being considerably more intuitive, and naturally avoiding subtleties associated with magnetization currents. I will eventually present a few calculations using the derived quantum kinetic equation: - the local thermal Hall current of topological magnons in a collinear antiferromagnet, - the energy density and local currents in a skyrmion lattice.

MA 10.11 Mon 17:45 EB 107

Exploration of magnetism and flat bands in novel Kagome magnets — •Ryo Misawa[1], Rinsuke Yamada[1], Ryota Nakano[1], Milena Jovanovic[2], Maxim Avdeev[3], Taka-hisa Arima[4,5], Yusuke Nambu[6,7,8], Leslie Schoop[9], and Max Hirschberger[1,4] — [1]Dep. of Applied Physics, Univ. of Tokyo, Japan — [2]Dep. of Chemistry, North Carolina State Univ., USA — [3]ANSTO, Australia — [4]RIKEN CEMS, Japan — [5]Dep. of Advanced Materials Science, Univ. of Tokyo, Japan — [6]Inst. Materials Res., Tohoku Univ., Japan — [7]FOREST, Japan Science and Technology Agency, Japan — [8]Organization for Advanced Studies, Tohoku Univ., Japan — [9]Dep. of Chemistry, Princeton Univ., USA

Kagome metals, a class of materials intrinsically possessing both Dirac cones and flat bands, have shown their versatility as a platform for exotic quantum phases of matter, such as superconductivity and charge order. However, the interplay between flat bands and magnetism remains unexplored. We will talk about our exploration of novel Kagome magnets, where the magnetic contributions come from rare-earth elements, and flat bands arise near the Fermi energy from the transition metal.

MA 11: Functional Antiferromagnetism

Time: Monday 15:00–18:45 Location: EB 202

MA 11.1 Mon 15:00 EB 202

Anisotropic magneto-transport properties in a short period helical magnet — •Ryota Nakano[1], Rinsuke Yamada[1], Sebastian Esser[1], Masaki Gen[2], Akiko Kikkawa[2], Yasujiro Taguchi[2], Maurice Colling[3], Jan Masell[2,3], Masashi Tokunaga[2,4], Hajime Sagayama[5], Hiroyuki Ohsumi[6], Yoshikazu Tanaka[6], Takahisa Arima[2,7], Yoshinori Tokura[1,2,8], and Max Hirschberger[1,2] — [1]Dep. of Applied Physics, University of Tokyo, Japan — [2]RIKEN CEMS, Japan — [3]Inst. of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany — [4]ISSP, University of Tokyo, Japan — [5]Inst. of Materials Structure Science, KEK, Japan — [6]RIKEN SPring8, Japan — [7]Dep. of Advanced Materials Science, University of Tokyo, Japan — [8]Tokyo College, University of Tokyo, Japan

Antiferromagnetic materials have recently attracted considerable attention due to their potential in future spintronic applications thanks to numerous characteristic features: they are robust against external magnetic field, produce no stray field, and display ultrafast dynamics. Anisotropic magnetoresistance (AMR) effect is one way to electrically read out spin textures of antiferromagnets. However, AMR has been so far studied mainly on collinear magnets and its amplitude tends to be small. In this presentation, we will show that partial Fermi surface gapping through Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions can enlarge AMR in a short period helical magnet and show some experimental results of a rare-earth-based target material.

MA 11.2 Mon 15:15 EB 202

Exchange spin-orbit coupling and unconventional p-wave magnetism — •Anna Birk Hellenes[1], Tomáš Jungwirth[2,3], Jairo Sinova[1,2], and Libor Šmejkal[1,2] — [1]JGU Mainz — [2]FZU Prague — [3]University of Nottingham

Relativistic spin-orbit coupling is a cornerstone in fundamental and applied research, governing phenomena such as spin Hall effects and topological insulators. The mechanism arises from the Dirac equation in non-centrosymmetric crystals and is typically confined to meV scales unless introducing heavy elements. In this work, we unveil a previously overlooked mechanism based on a magnetic analog of p-wave He-3 superfluidity that does not require heavy elements. Our mechanism shares the characteristic signature of spin-orbit coupling with the Dirac approach – namely, antisymmetric, p-wave, time-reversal-invariant spin polarization in the band structure. Unlike the relativistic Dirac equation, our spin-orbit coupling emerges from the magnetic exchange interaction in non-centrosymmetric crystals exhibiting a non-collinear spin order. We predict giant spin splitting magnitudes on the order of hundreds of meV in a realistic material candidate, namely antiperovskite Ce_3InN. Our findings open avenues for giant exchange spin-orbit coupling phenomena in materials comprising abundant light elements, with implications ranging from spintronics and nanoelectronics to topological matter [1].

[1]: Hellenes, Jungwirth, Sinova, and Šmejkal, arXiv:2309.01607.

MA 11.3 Mon 15:30 EB 202

Non-Volatile Spin-Orbit Torque Driven Antiferromagnetic Memristor — •Joao Godinho[1], Pradeep Rout[1], Ruslan Salikhov[2], Olav Hellwig[2,3], Zbynek Soban[4], Ruben Otxoa[5], Kamil Olejnik[4], Tomas Jungwirth[4,6], and Joerg Wunderlich[1,4] — [1]University of Regensburg, Regensburg, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Institute of Physics, Chemnitz University of Technology, Chemnitz, Germany — [4]Institute of Physics, ASCR, Prague, Czech Republic — [5]Hitachi Cambridge Labyoratory, Cambridge, United Kingdom — [6]School of Physics and Astronomy, University of Nottingham, United Kingdom

Magnetic data storage is based on the switching and detection of energetically degenerate ferromagnetic ground states with reversed magnetization separated by a sufficiently high energy barrier to maintain the long-term non-volatility of the stored data. Therefore, exploiting the many advantages of zero net moment antiferromagnets (AFM) for fast and energy-efficient magnetic storage will also rely on the realization of switching and detecting stable AFM states with reversed magnetic order. Here we show switching between non-volatile states with opposite Néel vector detections in a compensated out-of-plane synthetic AFM. The manipulation of the AFM order is achieved by generating relativistic effective spin-orbit fields and its detection via higher-order magneto-transport responses. Furthermore, besides the storing of binary "0" or "1" corresponding to two fully polarized magnetic states with reversed Néel vectors, we also show that partial switching enables the realization of non-volatile memristor type of devices.

MA 11.4 Mon 15:45 EB 202

Impact of growth conditions on magnetic anisotropy and magnon Hanle effect in α-Fe_2O_3 — •Monika Scheufele[1,2], Janine Gückelhorn[1,2], Matthias Opel[1], Akashdeep Kamra[3], Hans Huebl[1,2,4], Rudolf Gross[1,2,4], Stephan Geprägs[1], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, BAdW, Garching, Germany — [2]TUM School of Natural Sciences, Physics Department, TUM, Garching, Germany — [3]IFIMAC and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [4]Munich Center for Quantum Science and Technology, Munich, Germany

The antiferromagnetic insulator α-Fe_2O_3 exhibits a spin-reorientation transition (Morin transition) at $T_M = 263\,K$ – a feature often absent in thin films. To tune T_M, we investigate the impact of different growth conditions on the magnetic anisotropy in α-Fe_2O_3 films [1]. Unlike for films deposited in a molecular oxygen atmosphere, we observe a finite T_M for those grown in atomic oxygen even down to a thickness of 19 nm. Furthermore, we observe a clear impact of the growth conditions on the magnon Hanle effect, i.e. the precession of magnon pseudospin around its equilibrium pseudofield in easy-plane antiferromagnets. The maximum magnon Hanle signal is significantly enhanced and the peak position shifted to lower magnetic field values for films grown in atomic oxygen, suggesting changes in the magnetic anisotropy. This shows that the growth conditions allow to fine-tune the magnetic anisotropy in α-Fe_2O_3 and thereby to engineer the magnon Hanle effect.

[1] M. Scheufele *et al.*, APL Mater. **11**, 091115 (2023).

MA 11.5 Mon 16:00 EB 202

Hexagonal MnTe with Antiferromagnetic Spin Splitting and Hidden Rashba-Dresselhaus Interaction for Antiferromagnetic Spintronics — Suman Rooj, Jayita Chakraborty, Abhijeet Kumar, and •Nirmal Ganguli — Department of Physics, Indian Institute of Science Education and Research Bhopal, Bhauri, Bhopal 462066, India

Hexagonal MnTe emerges as a critical component in designing magnetic quantum heterostructures, calling for a detailed study. After finding a suitable combination of exchange-correlation functional and corrections, our study within *ab initio* density functional theory uncovers an insulating state with a preferred antiferromagnetic order. We compute the exchange interaction strengths to estimate the antiferromagnetic ordering temperature via Monte Carlo calculations. Our calculations and symmetry analysis reveal a large spin splitting in the system due to the antiferromagnetic order without considering spin-orbit interaction, except in the k_x-k_y plane. Critically examining the band dispersion and spin textures obtained from our calculations and comparing them with an insightful symmetry analysis and analytical model, we confirm a combined Rashba-Dresselhaus interaction in the k_x-k_y plane, around the K point of the system. Our results and insights would help design heterostructures of MnTe for technological applications.

https://doi.org/10.1002/apxr.202300050

MA 11.6 Mon 16:15 EB 202

Magnetization Dynamics in α-Fe_2O_3/NiFe Thin Film Bilayers — •Hassan Al-Hamdo[1], Tobias Wagner[2], Philipp Schwenke[1], Gutenberg Kendzo[1], Misbah Yaqoob[1], Maximilian Dausend[1], Laura Scheuer[1], Tamara Azevedo[1], Vitaliy I. Vasyuchka[1], Philipp Pirro[1], Olena Gomonay[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institute of Physics, JGU Mainz, 55099 Mainz, Germany

We experimentally investigate the magnetization dynamics in exchange-coupled bilayers of α-Fe_2O_3/$Ni_{80}Fe_{20}$ (Py). α-Fe_2O_3 is a canted antiferromagnet with small magnetic moment along the c-axis above the Morin temperature $T_M \approx 260$ K. Below T_M, α-Fe_2O_3 is a collinear antiferromagnet with Néel vector along the c-axis [1-3]. We deposit polycrystalline 10-nm Py thin films on α-Fe_2O_3 crystals and measure the bilayer magnetization dynamics as a function of temperature using broadband ferromagnetic resonance. We observe that the coupling of dynamic α-Fe_2O_3 and Py moments depends on both: temperature and crystalline orientation of α-Fe_2O_3, resulting in qualitatively different dynamics than previously observed by us in Mn_2Au/Py [4].

[1] D. Schroeer *et al*, Phys. Rev. Lett. **19**, 632 (1967).
[2] G. Haigh *et al*, Philos. Mag. **2**, 877-890 (1957).
[3] G. Rollmann *et al*, Phys. Rev. **B 69**, 165107 (2004).
[4] H. Al-Hamdo *et al*, Phys. Rev. Lett. **131**, 046701 (2023).

MA 11.7 Mon 16:30 EB 202

Revealing the higher-order spin nature of the Hall effect in non-collinear antiferromagnet Mn3Ni0.35Cu0.65N — •Adithya Rajan[1], Tom G. Saunderson[1], Fabian R. Lux[1], Dongwook Go[2], Hasan M. Abdullah[3], Arnab Bose[1], Udo Schingenschögl[3], Aurélien Manchon[4], Yuriy Mokrousov[1,2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, 52424 Jülich, Germany — [3]King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia — [4]CINaM, Aix-Marseille Université, CNRS, Marseille, France

We reveal [1] the complex origin of the anomalous Hall effect arising in noncollinear antiferromagnets by performing Hall measurements with fields applied in selected crystalline directions. Our coplanar magnetic field geometry goes beyond the conventional perpendicular field geometry used for ferromagnets and allows us to suppress any magnetic dipole contribution. We map the in-plane anomalous Hall contribution and demonstrate a 120 ° symmetry governed by the octupole moment at high fields. At low fields we subsequently discover a surprising topological Hall-like signature, and, from a combination of theoretical techniques, we show that the spins can be recast into dipole, emergent octupole and noncoplanar effective magnetic moments. These coexisting orders enable magnetization dynamics unachievable in either ferromagnetic or conventional collinear antiferromagnetic materials.

[1] A. Rajan, et al., arXiv:2304:10747 (2023)

15 min. break

MA 11.8 Mon 17:00 EB 202

Electronic structure of epitaxial $CuFeS_2$ thin films — •Anders Christian Mathisen, Richard Justin Schenk, Stefanie Suzanne Brinkman, Xin Liang Tan, Matthias Hartl, Christoph Brüne, and Hendrik Bentmann — Center for Quantum Spintronics, Department of Physics, NTNU Trondheim, Norway

Chalcopyrite, $CuFeS_2$, has over the years seen interest in many areas, often due to its thermoelectric properties, and as a source of copper. More recently, the material has gained attention as an antiferromagnetic semiconductor with a high Néel temperature ($T_N = 823$ K). $CuFeS_2$ is a collinear antiferromagnet with alternating spin-polarized planes along the *c*-direction of the body-centered tetragonal unit cell (space group $I\bar{4}2d$, No. 122). This is especially useful in the field of ultra-fast electronics, where the high-frequency spin dynamics and robustness against external magnetic fields plays an essential role. We present epitaxial growth of $CuFeS_2$ thin films on Si(001) substrates using molecular beam epitaxy (MBE). We probed the electronic structure of these films using laboratory-based photoelectron momentum microscopy and soft X-ray angle-resolved photoemission spectroscopy (ARPES). We compare the experimental findings to the results of *ab initio* calculations based on density functional theory. Our results promote $CuFeS_2$ thin films as a candidate for device concepts in antiferromagnetic spintronics.

MA 11.9 Mon 17:15 EB 202

The impact of local exchange coupling on spin-Hall effects measurements in non-collinear antiferromagnets — •Rouven Dreyer[1], James M. Taylor[1], Piet Urban[1], Binoy K. Hazra[2], Stuart S. P. Parkin[2], and Georg Woltersdorf[1,2] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, 06120 Halle, Germany

Non-collinear antiferromagnets (AFs) have been found to serve as an efficient source of intrinsic spin Hall effect (SHE) relevant for spintronic devices. However, the role of their chiral domain structure, and the transmission of the resulting spin current across interfaces with ferromagnets (FMs), remain open questions. Using a combination of electrically-detected spin-torque ferromagnetic resonance (ST-FMR) and optically-detected super-Nyquist-sampling magneto-optical Kerr effect (SNS-MOKE) measurements, we investigate the SHE generated by the non-collinear spin texture of Mn_3Ir in heterostructures with $Ni_{80}Fe_{20}F$. The enhanced damping due to interfacial exchange coupling between the AF and FM complicates extraction of the spin Hall angle (SHA) using ST-FMR. In contrast, SNS-MOKE studies allow for a local detection of the SHA, and reveal modifications of the coupling-induced anisotropy upon exposure to a combination of DC and RF currents. These findings open a path to quantify the SHE generated by an AF more accurately. Moreover, we demonstrate an efficient control mechanism for setting the exchange bias by exposing the AF to a combination of small bias fields and current induced heating.

MA 11.10 Mon 17:30 EB 202

Cubic Mn_3Ge thin films stabilized through epitaxial growth as a candidate noncollinear antiferromagnet — •James M Taylor[1], Anastasios Markou[2], Jacob Gayles[2], Yan Sun[2], Dominik Kriegner[2], Walter Schnelle[2], Peter Werner[1], Claudia Felser[2], and Stuart S P Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Halle — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

Metallic antiferromagnets with chiral spin textures induce Berry-curvature-driven anomalous and spin Hall effects that arise from topological bandstructure features. Here we use epitaxial engineering to stabilize thin films of Mn_3Ge with a cubic phase. This cubic phase is distinct from tetragonal ferrimagnetic and hexagonal noncollinear antiferromagnetic structures with the same chemical composition. First-principle calculations indicate that cubic Mn_3Ge will preferentially form an all-in/all-out triangular spin texture. We present evidence for this noncollinear antiferromagnetism through magnetization and magnetotransport measurements, finding a Néel temperature of 490 K. Simulation of the resulting bandstructure suggests the presence of Berry-curvature-generating features. These highlight cubic Mn_3Ge as a candidate material for topological antiferromagnetic spintronics.

MA 11.11 Mon 17:45 EB 202

Anisotropic magnetotransport enabled by low symmetry doped Hematite. — •Edgar Galindez-Ruales[1], Libor Šmejkal[1,2], Jairo Sinova[1,2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany. — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic.

This study investigates the origin of anisotropic magnetotransport in doped hematite. Experimental evidence demonstrates hematite's unconventional nature, challenging traditional magnetic paradigms and revealing distinct transport behaviors linked to altermagnetism. Doped hematite exhibits transverse voltage phenomena, coinciding with the spin-flop transition and featuring both odd and even components with strong crystal orientation dependencies. Advanced transport measurements reveal robust Hall conductivity contributions, deviating from expected symmetries in conventional antiferromagnets, suggesting the presence of altermagnetism [1]. Notably, a significant sign inversion in the Hall effect at a 45-degree orientation contradicts anticipated symmetries, highlighting the role of altermagnetic properties [2]. These findings elucidate the link between altermagnetism and crystal-direction-dependent transport, holding promising implications for spintronics. This study presents conclusive evidence supporting altermagnetic symmetries as a contributing mechanism shaping crystal-dependent magnetotransport in hematite. [1] L. Šmejkal et al., PRX 12, 040501 (2022). [2] E. Galindez-Ruales et al., ArXiv:2310.16907 (2023).

MA 11.12 Mon 18:00 EB 202

Surface-symmetry-driven phenomena in magnetoelectric Cr_2O_3 — •Oleksandr V. Pylypovskyi[1,2], Sophie F. Weber[3], Pavlo Makushko[1], Igor Veremchuk[1], Nicola A. Spaldin[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Kyiv Academic University, 03142 Kyiv, Ukraine — [3]Materials Theory, ETH Zürich, Wolfgang-Pauli-Strasse 27, 8093 Zürich, Switzerland

Antiferromagnetic (AFM) Cr_2O_3 is a unique collinear magnetoelectric material at room temperature. The bulk properties stemming from its magnetic symmetry render chromia of high interest for fundamentals and applications [1]. Features of the chromia surface remain much less explored. Here, we consider nominally compensated surfaces (m and a planes) of Cr_2O_3 [2]. We show that they provide a sizeable Dzyaloshinskii–Moriya interaction (DMI) determined by the surface magnetic symmetry point group and quantify it to be about $1\,\mathrm{mJ/m^2}$ by means of *ab initio* and micromagnetic approaches. The DMI leads to the development of nonzero surface magnetization $\vec{M}$ whose sign is uniquely determined by the AFM state. The m and a planes of Cr_2O_3 behave as the canted ferrimagnet and canted 4-sublattice antiferromagnet, respectively. The coupling of $\vec{M}$ to the direction of the Néel vector is shown by magnetotransport measurements.

[1] P. Makushko et al., Nat. Comm. 13, 6745 (2022). [2] O.V. Pylypovskyi, S. F. Weber et al., ArXiv:2310.13438 (2023).

MA 11.13 Mon 18:15 EB 202

Bi-directional current-induced switching of insulating antiferromagnetic thin films — •Christin Schmitt[1], Adithya Rajan[1], Grischa Beneke[1], Aditya Kumar[1], Tobias Sparmann[1], Hendrik Meer[1], Beatrice Bednarz[1], Rafael Ramos[2], Miguel Angel Niño[3], Michael Foerster[3], Eiji Saitoh[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]Department of Applied Physics, The University of Tokyo, Japan — [3]ALBA Synchrotron Light Facility, Spain

Antiferromagnets (AFMs) have gained interest as active elements in spintronic devices due to intrinsic dynamics in the THz range and the absence of stray fields. Efficient electrical writing and reading is necessary in terms of applications but challenging to realize. For insulating AFMs different switching mechanisms based on spin-orbit torques (SOTs) or thermomagnetoelastic effects have been put forward [1,2]. Here, we focus on ultrathin CoO/Pt films, where SOTs should be particularly pronounced. We observe that electrical pulses along the same path can lead to an increase or decrease of the electrical readout-signal, depending on the current density of the pulse. By photoemission electron microscopy (PEEM) employing the x-ray magnetic linear dichroism (XMLD) effect we shed light on this observation and determine for which situations this is a sign of two competing switching mechanisms or a result of the way the electrical measurement is conducted [3]. [1] T. Moriyama, et al., Sci. Rep. 8, 14167 (2018). [2] P. Zhang, et al., Phys. Rev. Lett. 123, 247206 (2019). [3] C.Schmitt, et al., arXiv:2303.13308.

MA 11.14 Mon 18:30 EB 202

Mechanisms of current driven Néel vector reorientation in Mn_2Au — •Guzmán Orero Gámez[1], Sonka Reimers[1], Lukas Odenbreit[1], Yuran Niu[2], Evangelos Golias[2], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 7, 55128, Mainz, Germany — [2]MAX IV Laboratory, Lund, Sweden

Current pulse driven Néel vector reorientation in metallic antiferromagnets (AFM) is one of the most promising concepts in antiferromagnetic spintronics. We have shown that such reorientation can be achieved in the metallic antiferromagnet Mn_2Au through two distinct mechanisms [Rei2023]. The first mechanism is the bulk Neél spin orbit torque, which originates from the unusual crystal structure of Mn_2Au in conjunction with strong spin-orbit coupling. The second mechanism originates from magnetoelastic coupling associated with current driven heating effects. In order to separate these two mechanisms experimentally, we use different geometries to alter the current path, thus changing the strain pattern. Additionally, we modify the pulse duration to reduce the heating. We show that both effects are present with the thermomagnetoelastic being dominant for longer pulse lengths. We use XMLD-PEEM with in-situ current pulsing together with AMR measurements to probe the reorientation of the Néel vector.

[Rei2023] *Reimers, S., et al. Current-driven writing process in antiferromagnetic Mn_2Au for memory applications. Nat. Commun.* ***14****, 1861 (2023).*

MA 12: Skyrmions I

Time: Monday 15:00–18:30 Location: EB 301

MA 12.1 Mon 15:00 EB 301

Reversible and Multidirectional Laser-Driven Motion of Chiral Domain Walls and Skyrmion Bubbles — •Kai Litzius[1], Jason Bartell[2], Lisa-Marie Kern[3], Shiyu Zhou[4], Daniel Suzuki[2], Pooja Reddy[2], Felix Steinbach[3], Bastian Pfau[3], Clemens von Korff Schmising[3], Stefan Eisebitt[3,5], Geoffrey Beach[2], Felix Büttner[1,6], and Lucas Caretta[4] — [1]University of Augsburg, Augsburg, Germany — [2]Massachusetts Institute of Technology, Cambridge, USA — [3]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin, Germany — [4]Brown University, Providence, USA — [5]Technische Universität Berlin, Berlin, Germany — [6]Helmholtz-Zentrum Berlin, Berlin, Germany

Noncolinear spin textures, including domain walls and skyrmions, are pivotal for advancing memory and logic applications. Current-driven devices, however, often face challenges in multidimensional motion, demanding intricate fabrication and a comprehensive understanding of spin texture dynamics in multidimensional space. In this study, we investigate the displacement of chiral solitons in ferrimagnetic Pt/GdCo/Ta films using ultrafast laser pulses, allowing for motion over arbitrary distances and directions. We highlight the critical role of the DMI in ensuring reproducible domain wall motion, preventing a destabilization and domain randomization due to precessional dynamics. Furthermore, we find that a negative temperature derivative of the domain wall energy caused by a laser-induced transient thermal gradient can explain the observation. This stresses the importance of the compensation point for light-induced effects in ferrimagnets.

MA 12.2 Mon 15:15 EB 301

3D Skyrmions in frustrated magnets — •Steven Schoenmaker, Ricardo Zarzuela, and Jairo Sinova — Johannes Gutenberg-University, Mainz, Germany

Three-dimensional magnetic solitons have received growing interest in the last few years driven by their intrinsic complexity and their potential use in topological computing and high-density memory storage. Noteworthy advancements have led to the experimental observation of hopfions [1] and skyrmion strings [2] in collinear magnets. Shankar skyrmions [3], the condensed matter realization of skyrmions present in baryonic matter and of which magnetic skyrmions are a two-dimensional analog, can emerge in spin systems described by a SO(3)-order parameter, such as frustrated magnets [4]. Motivated by this possibility, we discuss minimal phenomenological models for Shankar skyrmions in magnetically frustrated spintronic platforms, with an eye on their crystal phases.

[1] F. Zheng et al., Nature 623, 718-723 (2023).

[2] T. Yokouchi et al., Sci. Adv. 4, eaat1115 (2018); S. Seki et al., Nat. Comms. 11, 256 (2020).

[3] R. Shankar, J. Physique 38, 1405 (1977).

[4] R. Zarzuela, H. Ochoa and Y. Tserkovnyak, Phys. Rev. B 100, 054426 (2019).

MA 12.3 Mon 15:30 EB 301

Current induced dynamics of skyrmions in synthetic antiferromagnets — •Venkata Krishna Bharadwaj, Ricardo Zarzuela, and Jairo Sinova — 1Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, D-55099 Mainz, Germany

Magnetic skyrmions, distinctive for their topological magnetic whirls and a trivial magnetization configuration at their boundary, exhibit a non-zero skyrmion Hall angle during current-driven dynamics, owing to their inherent topological nature in ferromagnets [1]. This characteristic poses a challenge for practical applications. However, this effect is suppressed for skyrmions in synthetic antiferromagnets (SAFs), due to the overall zero topological charge in SAFs [2]. Recent experimental observations of skyrmions at room temperature in SAFs [3] have opened up promising avenues for realizing extremely small and mobile skyrmions, crucial for various spintronic applications. This work investigates the current-driven dynamics of skyrmions in compensated SAFs, evaluating the impact of interlayer coupling and current strengths on the Hall angle. Additionally, the model is expanded to include ferrimagnets.

[1] K. Litzius et al., Nat. Phys. 13, 170 (2017). [2] X. Zhang et al, Nat. Commun. 7, 10293(2016) [3] T. Dohi et al, Nat. Commun. 10, 5153 (2019)

MA 12.4 Mon 15:45 EB 301

Walking Skyrmions: directed movement in oscillating magnetic fields — •Alla Bezvershenko, Hannah Dürschmidt, Leon-Sascha Gernert, and Achim Rosch — Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany

Magnetic skyrmions are topologically non-trivial spin textures that attract great interest, offering a possible avenue towards novel spintronics applications. One of the reasons for it are small critical current densities needed to depin the skyrmion lattice. Pinning by disorder remains arguably one of the most important obstacles for all skyrmion-based non-equilibrium experiments and the creation of useful skyrmion devices. In this work, we introduce an elastic model for skyrmion strings in the bulk MnSi in the presence of pinning forces under oscillating magnetic fields. We discuss a remarkably rich non-equilibrium phase diagram of this model and find periodic magnetic driving schemes, under which a directed motion of skyrmion strings becomes possible.

MA 12.5 Mon 16:00 EB 301

Meron-antimeron lattice in Gd_2PdSi_3 and its topological Hall effect — •Leonie Spitz[1,2], Sebastian Esser[3], Fehmi Sami Yasin[2], Kamil Kolincio[2], Takashi Kurumaji[2], Sonia Francoual[4], Pablo Bereciartua[4], Akiko Kikkawa[2], Yasujiro Taguchi[2], Xiuzhen Yu[2], Taka-hisa Arima[2,5], Yoshinori Tokura[2,3,6], and Max Hirschberger[2,3] — [1]Paul-Scherrer-Institut, Switzerland — [2]RIKEN Center for Emergent Matter Science, Japan — [3]Dept. of Applied Phys., The University of Tokyo, Japan — [4]PETRA-III Synchrotron, DESY, Germany — [5]Dept. of Adv. Materials Science, The University of Tokyo, Japan — [6]Tokyo College, The University of Tokyo, Japan

Merons and antimerons are triple-**q** spin textures with winding number $n = \pm 1/2$. Apart from the winding number, meron/antimeron lattices differ from a skyrmion lattice in the phase between their constituent helical spin-density waves [1]. A skyrmion lattice accompanied by a large topological Hall effect was found in the centrosymmetric frustrated triangular lattice magnet Gd_2PdSi_3 in a magnetic field [2]. We focused on the zero-field ground state of Gd_2PdSi_3 and identified its triple-**q** magnetic structure as a meron-antimeron lattice. We studied the characteristics of the transition between the meron-antimeron phase and the skyrmion phase in Gd_2PdSi_3 to elucidate which degree of freedom is driving the transition in this case [3].

[1] S. Hayami *et al.*, Nat. Commun. **12**, 6927 (2021) [2] T. Kurumaji *et al.*, Science **365**, 914-918 (2019) [3] L. Spitz *et al.*, manuscript in preparation

MA 12.6 Mon 16:15 EB 301

The mechanism and timescale of skyrmion localization during all-optical topological switching — •Daniel Metternich[1,2], Michael Schneider[3], Torstein Hegstad[4], Giuseppe Mercurio[5], Riccardo Battistelli[1,2], Christopher Klose[3], Victor Deinhardt[1,2], Krishnanjana Puzhekadavil Joy[2], Manas Patra[1,2], Steffen Wittrock[1], Marcel Möller[6], Sergey Zayko[6], Claus Ropers[6], Johan Mentink[4], Bastian Pfau[3], and Felix Büttner[1,2] — [1]Helmholtz-Zentrum Berlin, Germany — [2]Universität Augsburg, Germany — [3]Max-Born-Institut, Germany — [4]Radboud Universiteit, Netherlands — [5]EuXFEL, Hamburg, Germany — [6]Max-Planck-Institut, Göttingen, Germany

Heating a Co/Pt-multilayer with an optical laser pulse can create skyrmions at picosecond timescales. While the nucleation of these features is understood as being facilitated by transient fluctuations, the mechanisms of localization during this process has remained a puzzle.

Here, we present a real-time study of the skyrmion localization dynamics, conducted via time resolved SAXS at the EuXFEL. Using a periodic grid of ion irradiated areas (where the magnetic anisotropy is reduced), we can distinguish in the Fourier-space scattering signal between the time evolution at localization centers and evolution of homogeneous fluctuations. We observe that the localization process sets in only after a phase of homogeneous, fluctuation-driven nucleation events. Atomistic simulations and analytical modeling show that the localization is driven by a larger annihilation energy barrier and hence a lower skyrmion decay rate in the ion-irradiated areas.

MA 12.7 Mon 16:30 EB 301

Quantum Skyrmion Operator in Chiral Magnets — •Andreas Haller[1], Sebastián A. Díaz[2], Wolfgang Belzig[2], and Thomas L. Schmidt[1] — [1]University of Luxembourg, Luxembourg — [2]University of Konstanz, Germany

In this talk, we discuss a variational Ansatz to represent quantum skyrmions as bosonic operators. The Ansatz contains and treats independently two fundamentally different terms: the classical magnetic order, and a "quantum cloud" of local spin-flip excitations. Interestingly, we find two distinct regions in the single-skyrmion state diagram of the model: one where leading quantum corrections around the classical magnetic order are targeted by standard linear spin-wave (SW) theory and one that demands an interacting SW theory. Using matrix product state simulations, we verify that a two-skyrmion quantum ground state indeed satisfies bosonic exchange statistics on large distances, which paves the way toward a coarse-grained bosonic description of intriguing many-body quantum phases such as skyrmion superfluids.

15 min. break

MA 12.8 Mon 17:00 EB 301

Pressure tuning of the anomalous Hall effect in the antiskyrmion compound Mn1.4Pt0.9Ir0.1Sn — •Parul Devi[1,2], Krishna Kant Dubey[3], Moaz Elghazali[1], Praveen Vir[4], Marc Uhlarz[1], Boby Joseph[5], Chandra Shekhar[4], Sanjay Singh[3], Claudia Felser[4], and Toni Helm[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [3]Indian Institute of Technology (Banaras Hindu University), Varanasi 221005, India — [4]Max Planck Institute for Chemical Physics of Solids, 01187, Dresden, Germany — [5]Elettra-Sincrotrone Trieste Strade Statale 14, Km 163.5 in Area Science Park, Basovizza 34149, Italy

We report on the pressure evolution of the anomalous Hall effect (AHE) in the antiskyrmion compound Mn1.4Pt0.9Ir0.1Sn. Herein, the observation of the isostructural phase transition in an antiskyrmion host tetragonal compound Mn1.4Pt0.9Ir0.1Sn at pressure * 20 GPa is presented. The magnetotransport and Hall-effect response of a single crystalline can be continuously tuned by the application of hydrostatic pressure * 30 GPa. We uncover a pressure-induced evolution at the low-temperature state of Mn1.4Pt0.9Ir0.1Sn into a distinct phase reminiscent of long-range ferromagnetism. This state is characterized by a steep negative magnetoresistance and an enhanced AHE with hysteretic behavior depending on the external magnetic field.

MA 12.9 Mon 17:15 EB 301

In-situ correlation of the Hall effect with the occurrence of topological magnetic phases — •S. Schneider[1,2], V. Bhatia[2], A. Yadav[2], S. Waddy[2], D. A. Mayoh[3], G. Balakrishnan[3], T. Sato[2], Y. Pivak[4], D. Pohl[1], A. Thomas[5], D. J. Reilly[2], B. Rellinghaus[1], J. M. Cairney[2], and M. Garbrecht[2] — [1]Dresden Center for Nanoanalysis (DCN), TU Dresden, Germany — [2]The University of Sydney, Australia — [3]University of Warwick, United Kingdom — [4]DENSsolutions, Netherlands — [5]IFW Dresden, Germany

Skyrmions are potential future nanoscale information carriers since they can be electrically manipulated and detected. Magnetic imaging in a transmission electron microscope (TEM) has proven extremely valuable for unveiling the details of these magnetic solitons. Hall effect measurements on such spin textures are usually conducted on samples that differ substantially in size and morphology from those investigated in a TEM. Since the stability of skyrmions is highly sensitive to the sample geometry, the correlation of magneto-transport and TEM data is problematic if not conducted on identical samples. We have therefore devised an in-situ measurement platform that bridges this gap and allows for magneto-transport measurements in-situ in a TEM. We correlate the Hall effect in a $Co_8Zn_9Mn_3$ lamella with the occurrence of topologically protected magnetic phases such as the helical phase and skyrmions. Our new setup provides the field dependence of the Hall voltage while simultaneously monitoring the magnetic phases in detail, thereby providing valuable insights into the existence and nature of the intensely debated electrical signature of skyrmionic structures.

MA 12.10 Mon 17:30 EB 301

Exploring the variety of chiral magnetic textures in $Mn_{1.4}PtSn$ — •M. Winter[1,2,3], M.C. Rahn[4], A.S. Sukhanov[4], S. Schneider[2], A. Tahn[2], D. Pohl[2], P. Vir[1], T. Helm[6], A. Thomas[4], A. Pignedoli[8], M. Azhar[8], K. Everschor-Sitte[8], J. Geck[4], G. van der Laan[7], T. Hesjedal[5,7], C. Felser[1], and B. Rellinghaus[2] — [1]MPI CPfS, Dresden, Germany — [2]DCN, TU Dresden, Germany — [3]IFW Dresden, Germany — [4]IFMP, TU Dresden, Germany — [5]Univ. Oxford, UK — [6]HZDR, Dresden, Germany — [7]Diamond Light Source, UK — [8]Univ. Duisburg-Essen, Germany

Combining in-situ Lorentz transmission electron microscopy (LTEM) and resonant elastic x-ray scattering (REXS) allows for an unambiguous correlation of magnetic scattering patterns with their underlying real space magnetic textures. We have applied this approach to explore the rich variety of magnetic textures emanating from basic chiral motifs in $Mn_{1.4}PtSn$. Supported by theoretical calculations and micromagnetic simulations, our experiments show that stripe domains, which are stabilized by the uniaxial magnetic anisotropy, rather than the so far assumed helical phase constitute the magnetic ground state of the material. Upon applying an external magnetic field, the stripe domains transform into a magnetic fan state or a chiral soliton lattice, depending on whether the field is applied within the plane of the anisotropic DMI or perpendicular to it, respectively. The findings allow to understand the kinetic pathways towards the formation of both non-topological bubbles and antiskyrmion lattices in $Mn_{1.4}PtSn$. The work is supported by DFG (SPP2137) and by MPG (IMPRS-CPQM).

MA 12.11 Mon 17:45 EB 301

Skyrmonic device for three dimensional magnetic field sensing enabled by spin-orbit torques — •Sabri Koraltan and Dieter Suess — Physics of Functional Materials, Faculty of Physics, University of Vienna, Vienna, Austria

Magnetic skyrmions are topologically protected magnetic solitons that are promising for storage or computing applications. In this work, we demonstrate that we can use a skyrmion device based on [W/CoFeB/MgO]xN multilayers for three-dimensional field sensing enabled by spin-orbit torques (SOT). We stabilize isolated chiral skyrmions and stripe domains in the multilayers, as shown by magnetic-force microscopy images and micromagnetic simulations. We perform magnetic transport measurements to show that we can sense both in and out-of-plane magnetic fields by a differential measurement scheme in which the symmetry of the SOT leads to cancellation of the DC offset. With the magnetic parameters obtained with vibrating sample magnetometry and ferromagnetic resonance measurements, we perform micromagnetic simulations where we investigate the fundamental origin of the sensing signal. That is, the topological transformation between skyrmions and stripes leading to an increase in the transverse voltage due to the anomalous and topological Hall effects.

MA 12.12 Mon 18:00 EB 301

Novel effects in S4/D2d-symmetric magnets: hybrid antiskyrmions and helix-switches — •Jan Masell[1,2] and Fehmi S. Yasin[2] — [1]Karlsruhe Institute of Technology (KIT), Germany — [2]RIKEN CEMS, Japan

Magnetic materials which obey only an S4 symmetry, i.e., whose only symmetry is one 4-fold roto-inversion axis, were recently identified as hosting a number of new competing interactions, stabilizing various novel magnetic textures. I will present our recent works where we identified the complex three-dimensional structure of antiskyrmions in an S4-symmetric material. Combining micromagnetic modelling and tomographic vector field electron holography, we could show that antiskyrmions in soft magnets terminate via Néel type skyrmion caps on the surfaces, which topologically requires the stabilization of a pairs of (anti-)Bloch points underneath each surface.[1] This novel texture is a natural consequence of the competition between bulk type S4-symmetric DMI and dipolar interaction, thus, can be expected as a ground state in many more materials of S4 or D2d symmetry. The same competition of energies causes pinning of the helices in these materials. I will discuss our recent experiments which showed that the direction of the q-vector of these phases can be controlled by temperature gradients [2], and I will outline how the competition with in-plane anisotropy may give arise to much more complex orientation transitions of the stripy phase of these materials.

[1] F.S.Yasin, J.Masell, et al., arXiv:2308.14219
[2] F.S.Yasin, J.Masell, et al., Nat Comm 14, 7094 (2023)

MA 12.13 Mon 18:15 EB 301

Tunable topological magnetism in superlattices of nonmagnetic B20 systems — •Vladislav Borisov[1], Anna Delin[2,3,4], and Olle Eriksson[1,3] — [1]Uppsala University, Sweden — [2]KTH

Royal Institute of Technology, Stockholm, Sweden — [3]Wallenberg Initiative Materials Science for Sustainability (WISE) — [4]SeRC (Swedish e-Science Research Center), KTH Stockholm, Sweden

Using atomistic spin dynamics simulations, we predict topological magnetism in hitherto uninvestigated multilayers of B20 compounds. We address up to $2 \cdot 10^6$ spins in the simulations, with magnetic interactions calculated from density functional theory [1,2]. We assume atomically sharp interfaces. Our main focus is on FeSi/CoSi and FeSi/FeGe superlattices with varying number of layers and interface types. First, we show that finite magnetism appears near the FeSi/CoSi interfaces. B20 layers further away from the interface are non-magnetic, similarly to bulk FeSi and CoSi compounds. Our simulations [3] predict stable antiskyrmions in [001]-oriented FeSi/CoSi, intermediate skyrmions in [111]-oriented FeSi/CoSi, and Bloch skyrmions in the FeSi/FeGe(001) multilayer. The skyrmion sizes vary between 7 and 37 nm. The unusual characters of the topological textures can be attributed to the complex structure of the Dzyaloshinskii-Moriya matrix, which is quite different compared to known magnets. Importantly, we also show that it is possible to stabilize AFM skyrmions as well, which can be interesting for applications due to their zero skyrmion Hall effect.

1. A. Szilva *et al.*, Rev. Mod. Phys. 95, 035004 (2023).
2. arXiv:2310.08628. 3. arXiv:2309.14421.

MA 13: Micro- and Nanostructured Magnetic Materials

Time: Monday 15:00–17:00 Location: EB 407

MA 13.1 Mon 15:00 EB 407

Magneto-ionic Control of Magnetoresistance in FeOx/Fe/Au Aerogels Networks — •Martin Nichterwitz[1,2], Karl Hiekel[3], Daniel Wolf[2], Alexander Eychmüller[3], and Karin Leistner[1,2] — [1]TU Chemnitz, Germany — [2]IFW Dresden, Germany — [3]TU Dresden, Germany

Voltage control of magnetism by ionic approaches, such as the metal/metal oxide transformation in gated architectures, presents a promising pathway to low-power magnetic devices or magnetic actuation. Magneto-ionic (MI) manipulation has been reported mainly for thin films and nanoporous metal alloy structures so far, whereas 3D nanostructures are exciting from fundamental and application point of view.[1] A seldom investigated magnetic feature in MI is magnetoresistance (MR), that is often examined in film geometry. We demonstrate reversible MI ON-OFF switching of MR in 3D FeOx/Fe/Au aerogel networks.[2] Multi-layered Au aerogels function as template for magnetic functionalization, via self-terminated Fe electrodeposition (5-10 nm FeOx/Fe coating). The increased surface-to-volume ratio boosts the MI effect, that relies on reactive interfaces. At room temperature and a magnetic field of -2 T an average MR of -0.043% (-0.007%) for the reduction (oxidation) state is achieved, representing a 6-fold increase of the average MR via voltage. Future optimization of such magneto-ionically controlled 3D nanomaterials can advance the development in low-power sensors, computation or information storage devices. [1] Fischer et al., APL Mater. 8 (2020) 010701. [2] Nichterwitz et al., ACS Mater. Au (2023) in print

MA 13.2 Mon 15:15 EB 407

Three-dimensional magnetic nanotextures — •Oleksii M. Volkov[1], Oleksandr V. Pylypovskyi[1,2], Fabrizio Porrati[3], Florian Kronast[4], Jose A. Fernandez-Roldan[1], Attila Kákay[1], Alexander Kuprava[3], Sven Barth[3], Filipp N. Rybakov[5], Olle Eriksson[5], Sebastian Lamb-Camarena[6], Pavlo Makushko[1], Mohamad-Assad Mawass[4], Shahrukh Shakeel[1], Oleksandr V. Dobrovolskiy[6], Michael Huth[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, Dresden, Germany — [2]Kyiv Academic University, Kyiv, Ukraine — [3]Johann Wolfgang Goethe-Universität Frankfurt am Main, Frankfurt am Main, Germany — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [5]Uppsala University, Uppsala, Sweden — [6]University of Vienna, Faculty of Physics and Vienna Doctoral School in Physics, Vienna, Austria

Additive nanotechnologies enable curvilinear and three-dimensional (3D) magnetic architectures with tunable topology and functionalities surpassing their planar counterparts. Here, we reveal that 3D soft magnetic wireframe structures resemble compact manifolds and accommodate magnetic textures of high order vorticity determined by the Euler characteristic, χ: (i) self-standing tetrapods, $\chi = +2$, support four vortices and two antivortices, with a total vorticity of +2; (ii) wireframe structures with one loop, $\chi = 0$, possess equal number of vortices and antivortices; (iii) wireframe geometries with N holes, $\chi = 2(1 - N)$, enable the accommodation of a virtually unlimited number of antivortices.

MA 13.3 Mon 15:30 EB 407

Effect of In concentration on structure and magnetism of CoFeMnNi-based alloys prepared by High Energy Ball Milling — •Elisavet Papadopoulou, Ivan Tarasov, Tatiana Smoliarova, Lennart Endler, Benedikt Eggert, Michael Farle, and Natalia Shkodich — Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, 47057 Germany

We report the successful fabrication of ferromagnetic CoFeMnNiInx (x=0; 10; 20; 30 at.%) high entropy alloy microsized particles by short-term (60 min) high energy ball milling (HEBM) in Ar at 700/1400 rpm. The SEM/EDX and TEM/EDX analyses of all HEBM compositions showed the homogeneous distribution of the principal elements. A nanocrystalline soft magnetic single fcc CoFeMnNi alloy produced by HEBM exhibits a saturation magnetization Ms (310 K) of 46.5 Am2/kg, which is 2.5 times higher than those reported in [1]. The addition of 10 at.% of In leads to an enhancement of Ms by 16 % and an increase in coercivity Hc up to 21.7 kA/m (by 58 times). Fast annealing (30 s) at 950 K for the quaternary alloy leads to a drastic decrease of Ms to 13.44 Am2/kg, while for CoFeMnNiIn10 MS is doubled (112 Am2/kg, twice the one of Ni), which is ~ 10 times higher than for the quaternary In-free alloy. We acknowledge financial support from DFG (CRC/TRR 270 (project ID 405553726), projects A04, A03 & B05). [1] Hariharan, V.S., Karati, A., Parida, T. et al. J Mater Sci 55, 17204-17217 (2020).

MA 13.4 Mon 15:45 EB 407

Imaging of the 3D magnetic domain structure of a nanostructured Nd-Fe-B bulk magnet using X-ray magnetic tomography — Damian Günzing[1], •Philipp Klassen[1], Alex Aubert[2], Lukas Schäfer[2], Fernando Maccari[2], Manuel Guizar-Sicairos[3,4], Valerio Scagnoli[5,3], Mirko Holler[3], Enrico Bruder[2], Heiko Wende[1], Konstantin Skokov[2], Oliver Gutfleisch[2], Claire Donnelly[6], and Katharina Ollefs[1] — [1]Faculty of Physics, UDE, Duisburg, GER — [2]Materials Science, TU Darmstadt, GER — [3]PSI, Villigen, CH — [4]Institute of Physics, EPFL, Lausanne, CH — [5]Department of Materials, ETH Zürich, CH — [6]MPI for Chemical Physics of Solids, Dresden, GER

Nd-Fe-B magnets play a key role for sustainable energy conversion for example in wind turbines or electric motors due to their superior magnetic performance and high energy density. In this talk, we provide insights into the 3D magnetic domain structure of nanostructured Nd-Fe-B magnets obtained by X-ray magnetic tomography. We imaged the magnetic interaction domain structure inside the bulk of a nanostructured hot-deformed anisotropic nanocrystalline $Nd_2Fe_{14}B$ magnet to correlate the crystal and micro structure and the magnetic moment configuration. We demonstrate that surface effects, such as flux-closure domains, do not dominate the magnetic domain pattern at the surface and reveal the complex domain structure in deeper sections of the permanent magnet. We acknowledge funding by CRC TRR 270.

MA 13.5 Mon 16:00 EB 407

Geometric tuning of the structural and magnetic properties of magnetic thin films via deposition onto highly ordered arrangements of nanospheres — •Asmaa Qdemat[1], Emmanuel Kentzinger[1], Johan Buitenhuis[2], Sabine Pütter[3], Mai Hussein Hamed[1], Nadine Seidel[4,1], Connie Meinke Bednarski[1], Oleg Petracic[1,4], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS-2, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Institute for Biological Information Processes, Biomacro molecular Systems and Processes (IBI-4), Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Jülich Centre for Neutron Science (JCNS)

at Heinz Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Jülich GmbH, Garching, Germany — [4]Heinrich-Heine-University Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany

The use of curved surfaces as substrates for thin film deposition induces lateral variation in film thickness, which allows variation in the deposited material properties. [Co/Pd]n multilayers with differen Co thicknesses were deposited on a flat silicon substrate, and densely packed two-dimensional arrays of silica nanospheres with different radii of curvature formed by improved drop-casting method [1]. Scanning electron microscopy, X-ray reflectivity (XRR), grazing incidence small angle X-ray scattering, SQUID and neutron reflectivity were used to characterise the obtained nanostructure. Compared to the flat multilayer, the cap multilayer shows a different anisotropy axis direction. A change in coercivity as a function of film thickness and radius of curvature is also observed.[1] A. Qdemat, et.al., RSC Adv., 10, 2020

MA 13.6 Mon 16:15 EB 407

Exploring Sustainable Approaches for the Synthesis of Na β-type Hexagonal Ferrite Magnetic Nanoparticles and Their Application in the Electrochemical Detection of Cefixime — •Sajjad Hussain — Centre of Excellence in Solid State Physics, University of the Punjab, Lahore, Pakistan

The quantitative study of antibiotics is significant due to their extensive application in treating many diseases worldwide. Cefixime (Cfx) is a third-generation cephalosporin medicine used as an antibacterial. In the current project, using a ginger root extract, the sol-gel green methodology was used for sodium β-type hexagonal ferrite nanoparticles (NaFe11O17-NPs). The NaFe11O17-NPs were subjected to analytical characterization using X-ray diffraction (XRD), atomic force microscopy (AFM), field emission scanning electron microscopy (FE-SEM), X-ray photoelectron spectroscopy (XPS), and vibrating sample magnetometer (VSM) analysis. The characterization confirmed the prepared material's crystalline behaviour, surface morphology, particle size, surface area, and magnetic nature. The drop-casting method was used for an efficient electrochemical sensor by modifying a gold electrode (AuE) with sodium β-type hexagonal ferrite nanoparticles NaFe11O17-NPs/AuE to assist the sensitive and selective quantification of Cfx. The fabricated electrochemical method achieved a notably low detection limit of 14 nM. The developed sensor was applied successfully to quantitatively determine Cfx in clinical samples and pharmaceutical preparations with excellent recoveries from 95.20 to 102.48 %.

MA 13.7 Mon 16:30 EB 407

Magnetization dynamics of CoFe 3D tetrahedral nanostructures — •Bereket Ghebretinsae[1], Christian Schröder[2], Martin Lonsky[1], Mohanad Al Mamoori[1], Fabrizio Porrati[1], Michael Huth[1], and Jens Müller[1] — [1]Institute of Physics, Goethe University, 60438 Frankfurt (M), Germany — [2]Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Bielefeld 33619, Germany

Magnetic nanostructures have long attracted great research interest, especially because of their enormous relevance in technological applications, such as magnetic storage. In the past, the functionality of magnetic nanostructures has been limited mostly to two dimensions. However, recent advances in the synthesis of nanomaterials have enabled fabricating 3D nanostructures with complex geometries. The expansion into the third dimension leads to the emergence of new physical phenomena and the formation of complex spin textures, which potentially could be exploited in novel technologies. Here we present an in-depth study of the magnetization dynamics of CoFe 3D ferromagnetic nanostructure arrays fabricated via focused electron beam induced deposition (FEBID). The nanostructures were grown in two different configurations ontop of a micro-Hall sensor, and then studied via highly sensitive magnetic stray field measurements. There we detect characteristic magnetic switching cascades, which we explain, with the help of micromagnetic and macrospin simulations, as resulting from the reorientation dynamics of non-interacting uniaxial anisotropic magnetic grains, equal to a superposition of Stoner-Wolfarth particles.

MA 13.8 Mon 16:45 EB 407

Single-crystalline YIG nanoflakes with uniaxial in-plane anisotropy and various crystallographic orientations — •Roman Hartmann[1], Seema Seema[1], Ivan Soldatov[2], Michaela Lammel[1], Daphné Lignon[1], Xianyue Ai[1], Gillian Kiliani[1], Rudolf Schäfer[2,3], Andreas Erb[4], Rudolf Gross[4,5], Johannes Boneberg[1], Martina Müller[1], Sebastian Gönnenwein[1], Elke Scheer[1], and Angelo Di Bernardo[1,6] — [1]FB Physik, Universität Konstanz, Konstanz, Germany — [2]Institute for Emerging Electronic Technologies, IFW Dresden, Dresden, Germany — [3]Institut für Werkstoffwissenschaft, TU Dresden, Dresden, Germany — [4]Walther-Meißner-Institut, Garching, Germany — [5]School of Natural Sciences, TU München, Garching, Germany — [6]Dipartimento di Fisica, Università di Salerno, Fisciano, Italy

Yittrium iron garnet (YIG) is being heavily investigated for application in spintronic devices. However, for device integration thin-film YIG is problematic due to its low in-plane magnetic anisotropy (IMA), its large lattice parameter and limited accessibility of crystallographic orientations. To overcome this caveat, we have developed a method to fabricate single-crystal nanoflakes from bulk YIG crystals [1]. These nanoflakes are available in multiple crystallographic orientations with respect to the surface and show a strong uniaxial IMA due to their shape. They are weakly bound to the substrate and can be picked up using a dry transfer technique to stack them with other single-crystal materials into heterostructures or onto electrodes and waveguides.

[1] R. Hartmann et al. Preprint at arXiv:2309.12477 (2023).

MA 14: Focus Session: Frustrated Magnetism and Local Order (joint session MA/TT)

Recent experimental findings illustrate unexpected spin glass behavior in a variety of frustrated magnets. Often their description goes beyond conventional pictures of spin glasses. For instance, the interplay of antiferromagnetism and spin glass behavior was recently studied. Such systems could be used to study the gradual evolution of spin glass behavior in an itinerant magnet without a change of the crystallographic environment. In this context, the discovery of the so-called self-induced spin glass in elemental neodymium showed that glassy behavior can even exist in the absence of disorder, leading to local magnetic order in the absence of long-range order. This focus session brings together experts from different subfields of frustrated magnetism and with different experimental and theoretical expertise, in order to exchange conceptual ideas beyond "traditional" paradigms of spin glasses and frustrated magnetism. These conceptual ideas are linked to fields such as artificially built frustrated magnets (e.g. spin ice), multi-well systems with complex dynamics, or fragile magnetic systems that may exhibit complex magnetic order.

Coordinators: Daniel Wegner and Alexander A. Khajetoorians (Radboud University, Nijmegen)

Time: Tuesday 9:30–13:15 Location: H 1058

Invited Talk MA 14.1 Tue 9:30 H 1058

Neutron scattering studies of spin-freezing phenomena at quantum phase transitions — •Christian Pfleiderer — School of Natural Sciences, Department of Physics, Technical University of Munich, D-85748 Garching, Germany — Centre for QuantumEngineering (ZQE), Technical University of Munich, D-85748 Garching, Germany — Heinz Maier-Leibnitz Zentrum (MLZ), Technical University of Munich, D-85748 Garching, Germany — Munich Centre for

Quantum Science and Technology (MCQST), Technical University of Munich, D-85748 Garching, Germany

A cornerstone of the statistical and thermal physics of condensed matter systems concerns their energy landscape and the associated ergodicity. Conventional and topologically non-trivial forms of long-range magnetic order represent weak forms of non-ergodicity that allow to explore classical and quantum dynamics, as well as the origin and nature of topological protection. In contrast, strong forms of non- ergodicity related to glassy configurations and freezing transitions permit the comparison of quantum versus thermally driven relaxation as constrained, e.g., by disorder. Combining the results of neutron depolarization, neutron diffraction, and neutron spectroscopy with magnetization and ac susceptibility measurements, similarities and differences of spin freezing phenomena at selected quantum phase transitions will be presented. This includes the putative formation of reentrant spin glass behaviour in $Fe_{1-x}Cr_x$, a Kondo cluster glass in $CePd_{1-x}Rh_x$, and a spin liquid in $HgCr_2Se_2$ under pressure.

Invited Talk MA 14.2 Tue 10:00 H 1058

Frustrations, glassiness and complexity of spin systems with large spatial dimension — •Mikhail Katsnelson — Radboud University, Nijmegen, Netherlands

It was suggested some time ago [1] that spin system can behave as a glass without disorder, due to frustrations only (self-induced spin-glass state). Recent experimental discovery of glass-like magnetic state in elemental Nd at low temperatures [2] creates a very strong motivation to improve our theoretical understanding of such an opportunity. We have shown [3] that the glassiness without disorder can be derived quite rigorously for classical Heisenberg model in the limit of large spatial dimension, where an accurate and controllable mathematical treatment turns out to be possible.

For frustrated quantum spin systems, the sign structure of the ground state has a high complexity, in a sense that the machine learning of this structure is very difficult [4]. This problem however can be mapped to the classical Ising model of a very large dimension which allows to reach a progress in determining this sign structure [5].

[1]. A. Principi and M. I. Katsnelson, Phys. Rev. B 93, 054410 (2016); Phys. Rev. Lett. 117, 137201 (2016). [2] U. Kamber et al, Science 368, eaay6757 (2020); B. Verlhac et al, Nature Phys. 18, 905 (2022). [3] A. Mauri and M. I. Katsnelson, arXiv:2311.09124. [4] T. Westerhout et al, Nature Commun. 11, 1593 (2020). [5] T. Westerhout, M. I. Katsnelson, and A. A. Bagrov, Commun. Phys. 6, 275 (2023).

Invited Talk MA 14.3 Tue 10:30 H 1058

Self-Induced Spin Glass Phase and Thermally Induced Order in dhcp Nd — •Anders Bergman — Uppsala University, Uppsala, Sweden

Among the wide variety of magnetic orders found in frustrated magnets, one of the most intriguing phases is manifested by the spin glass state where the magnetization exhibit glassy dynamics, including ageing and memory effects. The peculiar dynamics of spin glass materials has historically been associated with disorder where magnetic frustration can cause an energy landscape with several local minima combined with larger energy barriers, resulting in non-ergodic behavior and glassy dynamics.

Recent theoretical and experimental findings have however indicated the existence of glassy dynamics in a material with limited chemical disorder: elemental and crystalline Nd [1]. In this talk, we will present results indicating that: I) the low temperature state of dhcp Nd can be described as a self-induced spin glass and II) dhcp Nd undergoes a phase transition from the self-induced spin glass phase to an ordered spin-spiral phase with increasing temperature [2].

Using first-principles DFT calculations of magnetic exchange interactions combined with atomistic spin dynamics simulations we can show that the complex magnetism of dhcp Nd is driven by an intrinsic frustration of the exchange interactions between Nd atoms at the cubic and the hexagonal sites in the dhcp structure.

[1] U. Kamber, et. al, Science 6757 368 (2020)
[2] B. Verlhac, et. al, Nature Physics 905 18 (2022)

MA 14.4 Tue 11:00 H 1058

Spatially resolved aging and rejuvenation in a self-induced spin glass — •Lorena Niggli[1], Julian H. Strik[1], Zhengyuan Liu[1], Anders Bergman[2], Mikhail I. Katsnelson[1], Daniel Wegner[1], and Alexander A. Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

Spin glasses are a puzzling form of magnetic matter lacking long range order and possessing multiple relaxation time scales indicative of aging. These findings are based on ensemble thermodynamic measurements, which leave more to be known about the behaviour of the magnetization locally. Recently, we have discovered that the low temperature magnetic phase of elemental neodymium behaves like a proposed self-induced spin glass relying solely on spin frustration in the absence of disorder for glassiness [1,2]. Here, we explore the aging behaviour of Nd(0001) using spin-polarized scanning tunneling microscopy in varying magnetic fields. We observe a transition from an initial state, reached after cooling into the glass phase, towards a distinct final state, as we perturb the system. Temperature cycling allows us to rejuvenate the system back into its initial state, which hints towards a thermally written memory in this glassy system. Using a new analysis method, we quantify the favourability of the observed local order as well as investigate its link to the energy landscape.

[1] U. Kamber et al., Science 368 (2020).
[2] B. Verlhac et al., Nature Physics 18 (2022).

MA 14.5 Tue 11:15 H 1058

Multipolar order in the 5d double perovskite Ba_2MgReO_6 from DFT+DMFT — Maximilian E. Merkel and •Claude Ederer — Materials Theory, ETH Zürich, Switzerland

We establish the effect of electronic correlations and strong-spin-orbit coupling on the emergence of the insulating state and the quadrupolar order in the magnetically frustrated 5d double perovskite Ba_2MgReO_6 (BMRO). BMRO exhibits a tetragonally distorted paramagnetic phase below $T_q \sim 33\,K$ and a non-collinear magnetically ordered state below $T_m \sim 18\,K$. Using density functional theory in combination with dynamical mean-field theory (DFT+DMFT), we demonstrate that BMRO should be classified as a normal Mott insulator where the spin-orbit coupling is not crucial for the formation of the insulating state. Our calculations further reveal a subtle interplay between the electronic quadrupolar order and the Jahn-Teller distortion, where the primary instability is of electronic origin but the coupling to the structural distortion determines the specific character of the emerging order.

15 min. break

Invited Talk MA 14.6 Tue 11:45 H 1058

Frustrated Quantum Devices: Pathways to leverage exotic order in novel spintronic technologies — •James Analytis — University of California at Berkeley, 366 Physics North, Berkeley, CA 94705, USA

Materials at the boundary of critical phase transitions are of significant fundamental interest, not least due because of their connection to unconventional superconductivity and quantum magnetism. One characteristic shared by many such systems is the presence of coupled order parameters that underlie these phase transitions. Here, we explore how this coupling manifests in the response of these materials when driven out of equilibrium by applied currents. We demonstrate how magnetic and charge textures can be electrically manipulated, suggesting possible applications for exotic materials in spintronics technologies.

MA 14.7 Tue 12:15 H 1058

Noncoplanar and chiral spin states on the way towards Néel ordering in fullerenes — •Attila Szabó[1], Sylvain Capponi[2], and Fabien Alet[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Laboratoire de Physique Théorique, Toulouse, France

Magnetic ordering can be detected in finite lattices through the emergence of Bragg peaks in ground-state structure factor or through the spectrum of low-energy excited states, which form an Anderson tower of states generated by Goldstone modes of the incipient symmetry breaking. In this talk, I will generalise these methods to large fullerenes, where incipient Néel ordering on the network of hexagonal faces is frustrated by a low density of pentagons. Using high-accuracy variational Monte Carlo based on group-convolutional neural networks, we obtain the symmetry-resolved low-energy spectrum of the spin-1/2 Heisenberg model on several highly symmetric fullerene geometries, including the famous C_{60} buckminsterfullerene. We show that their correlation functions contain high-intensity Bragg peaks consistent with Néel-like ordering, while the low-energy spectrum is organised into a tower of states. Competition with frustration, however, turns the simple Néel order into a noncoplanar one. Remarkably, we find and predict chiral incipient ordering in a large number of fullerene structures. Our findings may have interesting ramifications for the nature of superconductivity in metal fullerides.

MA 14.8 Tue 12:30 H 1058

Frustrated magnetism in novel layered Mott insulators. — •Sergii Grytsiuk[1], Mikhail I. Katsnelson[1], Erik G.C.P. van Loon[2], and Malte Rösner[1] — [1]Institute for Molecules and Materials, Radboud University, Heijendaalseweg 135, 6525AJ Nijmegen, The Netherlands — [2]NanoLund and Division of Mathematical Physics, Physics Department, Lund University, Sweden

Via ab initio down folding, we show that the layered van der Waals distorted kagome compounds Nb_3X_8 (X=Cl, Br, and I) are Mott insulators. We demonstrate that the monolayer of these compounds has a frustrated triangular AFM order, while in bulk, an intriguing interplay between intra- and interlayer AFM coupling promotes magnetic frustration further. We show that this leads to chiral in-plane spiralisation of frustrated triangular AFM order at high temperatures and strong collinear interlayer AFM coupling at low temperatures. Furthermore, we explain the "mystic" magnetic phase transition and the nature of the putative "non-magnetic" phase at low temperatures observed in Nb3Cl8, which has not been explained theoretically until now. Finally, our finding offers new opportunities for controlling such non-trivial frustrated magnetism in these layered Mott insulators via doping or substrate screening.

Invited Talk MA 14.9 Tue 12:45 H 1058

New Frontiers in Artificial Spin Ice: Phase Transitions in Two and Three Dimensions — •Gavin M. Macauley[1,2], Luca Berchialla[1,2], Aleksandra Pac[1,2], Tianyue Wang[1,2], Armin Kleibert[3], Valerio Scagnoli[1,2], Peter M. Derlet[4], and Laura J. Heyrderman[1,2] — [1]Laboratory for Mesoscopic Systems, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland — [2]Laboratory for Multiscale Materials Experiments, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [3]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Condensed Matter Theory Group, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

Artificial spin ices are arrays of strongly correlated nanomagnets, which are coupled through the dipolar interaction. While originally envisaged as a two-dimensional analogue to frustrated rare-earth pyrochlores, they are now studied since they exhibit behaviour such as glassiness and charge fragmentation, and topologically induced textures such as magnetic 'monopoles' [1]. In this talk, I will introduce artificial spin ice and discuss some recent work performed in the Laboratory for Mesoscopic Systems. By way of example, I will discuss how they can be used as a platform to study phase transitions by focusing on the example of a rotated kagome-like lattice in two-dimensions and an artificial spin ice based on the buckyball in three-dimensions. These systems have complex phase diagrams, with crossovers, phase transitions, and phase coexistence. [1] Skjaervo, S.H., Marrows, C.H., Stamps, R.L. and Heyderman, L.J. Nat. Rev. Phys. 2, 13-28 (2020).

MA 15: Topological Insulators and Weyl Semimetals (joint session MA/TT)

Time: Tuesday 9:30–13:00 Location: H 2013

MA 15.1 Tue 9:30 H 2013

behavior of Dirac fermion in non-symmorphic CeTX2 systems — •Sawani Datta[1,4], Khadiza Ali[2], Rahul Verma[1], Denis Vyalikh[3], Bahadur Singh[1], A Thamizhavel[1], Saroj P Dash[2], and Kalobaran Maiti[1] — [1]Tata Institute of Fundamental Research, Mumbai, India — [2]Chalmers University of Technology, Gotheborg, Sweden. — [3]DIPC, Donostia, San Sebastian, Spain — [4]Max Plank Institute for Solid State Research, Stuttgart, Germany

We have studied the behavior of Dirac fermions in the presence of strong electron correlation in nonsymmorphic Kondo lattice systems, CeTX2 (T=Cu/Ag, X-As/Sb) employing high-resolution angle-resolved photoemission spectroscopy [1]. Experiments reveal crossings of highly dispersive linear bands at the Brillouin zone boundary protected by non-symmorphic symmetry [2]. In addition, anisotropic Dirac cones are observed constituted by the square net Sb(As) 5p(4p) states forming a diamond-shaped nodal line. The Dirac bands are linear in a wide energy range with an unusually high slope and exhibit distinct Dirac points in these highly spin-orbit coupled systems. Along with these bulk crossings, CeCuAs2 also exhibits a surface Dirac crossing at the Γ-point. These results seed the emergence of an area of robust topological fermions even in the presence of strong correlation. [1] S. Datta et al. arXiv:2311.05278 [2] L. M. Schoop et al., Nat. Commun. 7, 11696 (2016).

MA 15.2 Tue 9:45 H 2013

Isotropic 3D topological phases with broken time reversal symmetry — Helene Spring[1], Anton R. Akhmerov[1], and •Daniel Varjas[2,3,4] — [1]Kavli Institute of Nanoscience, Delft University of Technology, P.O. Box 4056, 2600 GA Delft, The Netherlands — [2]Department of Physics, Stockholm University, AlbaNova University Center, 106 91 Stockholm, Sweden — [3]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany — [4]IFW Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, Helmholtzstr. 20, 01069 Dresden, Germany

Axial vectors, such as current or magnetization, are commonly used order parameters in time-reversal symmetry breaking systems. These vectors also break isotropy in three dimensional systems, lowering the spatial symmetry. We demonstrate that it is possible to construct a fully isotropic and inversion-symmetric three-dimensional medium where time-reversal symmetry is systematically broken. We propose an amorphous system with scalar time-reversal symmetry breaking, implemented by hopping through chiral magnetic clusters along the bonds. The average spatial symmetries alone protect a statistical topological insulator phase in this system. We demonstrate the topological nature of our model by constructing a bulk integer topological invariant, which guarantees gapless surface spectrum on any surface with several overlapping Dirac nodes, analogous to crystalline mirror Chern insulators. We also show the expected transport properties of a three-dimensional statistical topological insulator, which remains critical on the surface for odd values of the invariant.

MA 15.3 Tue 10:00 H 2013

Behavior of Dirac Fermions in Kondo lattice systems — •Kalobaran Maiti — Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai 400005, India

We studied the behavior of Dirac fermions in novel Kondo lattice system employing ARPES. We show that a binary system, SmBi show signature of multiple gapped and un-gapped Dirac cones in the band structure. Employing ultra-high-resolution ARPES, we discover destruction of a surface Fermi surface across the Neel temperature while the behavior of Dirac cones survive across the magnetic transition. ARPES data of a non-symmorphic Kondo lattice system, CeAgSb2 exhibit distinct Dirac cones as well as diamond-shaped nodal lines; the slope of these linear bands is unusually high, larger than that in graphene and maintains its high value in a wide energy range indicating robust high velocity of these relativistic particles. The slope becomes smaller in the vicinity of strongly correlated Ce 4f bands forming a kink; a unique case due to correlation induced effects.

References: 1. Sawani Datta et al., arXiv:2311.05278 2. A.P. Sakhya et al. Phys. Rev. Mater. 2021, 5, 054201. 3. A.P. Sakhya et al. Phys. Rev. B 2022, 106, 085132.

MA 15.4 Tue 10:15 H 2013

Strain control on band topology and surface states in antiferromagnetic EuCd2As2 — •Nayra Alvarez[1], Rodrigo Jaeschke[1], Venkata Krishna[1], Adrian Valadkhani[2], Roser Valenti[2], Libor Smejkal[1], and Jairo Sinova[1,3] — [1]Institut für Physik, Johannes Gutenberg Universität — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt — [3]Inst. of Physics Academy of Sciences of the Czech Republic

Topological semimetal antiferromagnets provide a rich source of exotic topological states which can be controlled by manipulating the orientation of the Neel vector, or by modulating the lattice parameters through strain. We investigate via ab initio density functional theory calculations, the effects of shear strain on the bulk and surface states in two antiferromagnetic EuCd2As2 phases with out-of-plane and in-plane spin configurations. We demonstrate the control of the band topology and how they can lead to hinge modes as well, which may prove useful to realize the long-sought after axion states and to stimulate further research in the field of strain effects on Dirac semimetals[1].

[1] Pari, Nayra A. Álvarez, et al. "Strain control of band topology and surface states in antiferromagnetic EuCd2As2." arXiv preprint arXiv:2310.19186 (2023)

MA 15.5 Tue 10:30 H 2013

Nonlocal Spin Dynamics Arising From Induced Interactions at the Interface of a Topological Insulator and a Ferromagnet — •Christian S. Johnsen and Asle Sudbø — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

In recent years, topologically stable magnetic textures called skyrmions have received much attention for their potential uses in information technology. One such use is making skyrmions the information carriers in low-dissipation information storage devices because skyrmions can be moved using exceedingly small currents. One proposed setup is to move them using a low-dissipation current on the surface of a topological insulator. In this work, an effective field theory for the spins in such a heterostructure is derived. The theory shows time-dependent induced spin-spin interactions such as DMI and the presence of non-negligible retardation effects which alter the system's spin dynamics. In particular, we derive an inertial term and various dissipative terms in the Landau-Lifshitz-Gilbert equation.

MA 15.6 Tue 10:45 H 2013

Surface reconstruction effects in thin films of Antiferromagnetic Topological Insulator $MnBi_2Te_4$ — •Shahid Sattar and Carlo Maria Canali — Department of Physics and Electrical Engineering, Linnaeus University, Kalmar SE-39231, Sweden

Intrinsic magnetic topological insulator $MnBi_2Te_4$ (MBT) characterized by a non-zero topological Z_2 index has recently gained significant interest and attention. Experiments on thin films of MBT have confirmed the presence of the anomalous quantum Hall and axion insulating phases in odd and even septuple-layer films respectively. In this work, we investigate surface reconstruction effects on topological characteristics in thin films of MBT using first-principles calculations and an effective $\mathbf{k} \cdot \mathbf{p}$ model Hamiltonian. We discuss the implications of surface reconstruction on both the Chern and axion insulating phases and discuss the presence of Rashba surface states for the latter. Our results provide a theoretical framework needed to elucidate the nature of surface reconstruction in magnetic TI thin films, which can be useful for their experimental realization.

MA 15.7 Tue 11:00 H 2013

The MT Protected Topological States and Local Symmetry in 2D Antiferromagnetic SrMn2Bi2 — •Hao Wang[1], Chengwang Niu[2], Libor Smejkal[3,4], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]School of Physics, State Key Laboratory of Crystal Materials, Shandong University, Jinan 250100, China — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [4]Institute of Physics Academy of Sciences of the Czech Republic, Cukrovarnicka 10, Praha 6, Czech Republic

Antiferromagnetic topological insulators (AFMTIs) represent a novel class of topological states for spintronics. Understanding symmetry protection and exploring AFMTIs with desirable properties are crucial. In this study, through first-principles calculations and symmetry analysis, we investigate the topological properties of monolayer SrMn2Bi2, demonstrating sensitivity to magnetic configurations. In the out-of-plane AFM ground state, we observe a gapless helical edge state protected by the mirror plane combined with time-reversal symmetry. In the FM state, this system resides in a quantum anomalous Hall phase, and topology trivial for in-plane magnetization. We show that the topological properties can be efficiently manipulated by strain. Additionally, constructing proper Wannier functions obeying symmetry constraints is crucial to avoid spurious states in surface spectra. Our work provides an ideal candidate for AFMTIs and guides the symmetry analysis of magnetic topological materials using Wannier functions.

15 min. break

MA 15.8 Tue 11:30 H 2013

Electrical Activity of Topological Chiral Edge Magnons — •Robin R. Neumann[1], Alexander Mook[2], Jürgen Henk[1], and Ingrid Mertig[1] — [1]Martin Luther University Halle-Wittenberg, Halle (Saale), Germany — [2]Johannes Gutenberg University, Mainz, Germany

Magnons, the bosonic quasiparticles of spin waves, have been predicted to feature similar topological phases as electrons. In particular, the topological band structure of the quantum Hall systems has its magnonic analogue in the topological magnon insulator (TMI), which hosts topologically protected chiral edge excitations. Beyond theoretical studies, however, there exist no direct experimental evidence of their existence as the lack of charge renders them invisible to most surface-sensitive probes.

In this talk I demonstrate how magnetoelectric coupling imparts an electric dipole moment to the chiral magnons that manifests in equilibrium and nonequilibrium. Considering a two-dimensional ferromagnetic TMI, an electric edge polarization perpendicular to the sample's edges is driven by thermal fluctuations of the collinear magnetic ground state in equilibrium. On the other hand, the TMI features a unique in-gap resonance in its electrical absorption spectrum that stems from the chiral magnons showcasing their electrical activity. These results suggest THz spectroscopy as promising probe for topological magnons.

MA 15.9 Tue 11:45 H 2013

Interplay of magnetism and band topology in $Eu_{1-x}Ca_xMg_2Bi_2$ (x=0, 0.5, 0.67) from first principles study — •Amarjyoti Choudhury, Narayan Mohanta, and Tulika Maitra — IIT Roorkee,India

The recent discovery of time-reversal symmetry-breaking magnetic Weyl semimetals (WSMs) has sparked extensive research in quantum topological materials. We systematically studied magnetic orders, electronic structure, and the interplay between magnetic order and band topology in $EuMg_2Bi_2$ (EMB) and its Ca-doped variant using density functional theory (DFT). Our investigation reveals various magnetic order-driven topological phases, such as a topological insulator in the A-type antiferromagnetic (A-AFM) phase with Eu moments along the b, a Dirac semimetal in the A-AFM phase with Eu moments along the c direction, and a Weyl semimetal in the ferromagnetic (FM) phase with Eu moments along the c direction. These phases are energetically close and tunable by external factors like magnetic field or chemical substitution. In the FM state of $EuMg_2Bi_2$, we identify an ideal Weyl semimetal with a single pair of Weyl points (WPs) close to the Fermi level along Γ-A direction. Doping with 50% and 67% Ca at Eu sites moves the WPs even closer to the Fermi level, making it highly desirable for applications. Additionally, the separation between WPs decreases in doped compounds, impacting anomalous Hall conductivity (AHC). Our first-principles calculation of AHC shows high peak values at these WPs, decreasing with Ca doping, indicating Ca as a potential external handle to tune AHC in this system.

MA 15.10 Tue 12:00 H 2013

Chiral spin textures in the B20 material family — •Iñigo Robredo[1], Jonas Krieger[2], Niels Schröter[2], Maia Vergniory[1], and Claudia Felser[1] — [1]MPI CPfS — [2]MPI Microstructure Physics

The spin texture of electronic bands has been studied for decades in magnetic materials due to its promising applications in the field of spintronics, which aims to exploit the spin degree of freedom. Recently, it has been shown that non-magnetic materials can present exotic spin textures, which makes them promising for microelectronics applications due to the lack of stray fields. In order to present non-trivial spin degeneracies, these systems break crystalline rotoinversion symmetries, and are thus structurally chiral. In this work we revisit the chiral toy model in space group 198 introduced in Ref [1] as a proxy for materials in the B20 family and study the spin textures as a function of spin-orbit coupling strength. We study the spin texture of the surface Fermi arcs, which has also attracted attention recently [2], and show that the spin-momentum locking varies along the surface BZ.

[1] Mao Lin, Iñigo Robredo, Niels B. M. Schröter, Claudia Felser, Maia G. Vergniory, and Barry Bradlyn Phys. Rev. B 106, 245101 [2] Jonas A. Krieger, Samuel Stolz, Inigo Robredo, et al, arXiv:2210.08221

MA 15.11 Tue 12:15 H 2013

Nonlinear optical diode effect in a magnetic Weyl semimetal — •Christian Tzschaschel[1,2], Jian-Xiang Qiu[2], Xue-Jian Gao[3], Hou-Chen Li[2], Chunyu Guo[4], Hung-Yu Yang[5], Cheng-Ping Zhang[3], Ying-Ming Xie[3], Yu-Fei Liu[2], Anyuan Gao[2], Damien

Bérubé[2], Thao Dinh[2], Sheng-Chin Ho[2], Yuqiang Fang[6,7], Fuqiang Huang[6,7], Johanna Nordlander[2], Qiong Ma[5], Fazel Tafti[5], Philip J.W. Moll[4], Kam Tuen Law[3], and Suyang Xu[2] — [1]Max Born Institute, Berlin, Germany — [2]Harvard University, Cambridge, USA — [3]Hong Kong University of Science and Technology, Hong Kong, China — [4]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [5]Boston College, Chestnut Hill, USA — [6]Shanghai Institute of Ceramics, Chinese Academy of Science, Shanghai, China — [7]College of Chemistry and Molecular Engineering Peking University, Beijing, China

We report the observation of a nonlinear optical diode effect (NODE) in the magnetic Weyl semimetal CeAlSi, where the magnetic state of CeAlSi introduces a pronounced directionality in the nonlinear optical second-harmonic generation (SHG). By physically reversing the beam path, we observe a strong directional contrast over a wide bandwidth exceeding 250 meV. Supported by first-principles calculations, we establish the linearly dispersive bands emerging from Weyl nodes as the origin of the extreme bandwidth. We further demonstrate current-induced magnetization switching and thus electrical control of the NODE in a spintronic device structure. Our results advance ongoing research to identify novel phenomena in magnetic quantum materials.

MA 15.12 Tue 12:30 H 2013

Origin of incommensurate magnetic order in rare-earth magnetic Weyl semimetals — •Juba Bouaziz[1], Gustav Bihlmayer[1], Christopher E. Patrick[2], Julie B. Staunton[3], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich JARA, D-52425 Jülich, Germany — [2]Department of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, United Kingdom — [3]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom

We investigate rare-earth magnetic Weyl semimetals through first-principles simulations, analyzing the connection between incommensurate magnetic order and the presence of Weyl nodes in the electronic band structure. Focusing on PrAlSi, NdAlSi, and SmAlSi, we demonstrate that the reported helical ordering does not originate from the nesting of topological features at the Fermi Surface or the Dzyaloshinskii-Moriya interaction. Instead, the helical order arises from frustrated isotropic short-range superexchange between the 4f moments facilitated by pd-hybridization with the main group elements. Employing a spin Hamiltonian with isotropic exchange and single-ion anisotropy we replicate the experimentally observed helical modulation. Funding: European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant No. 856538, project "3D MAGiC")

MA 15.13 Tue 12:45 H 2013

Surface magnon spectra of nodal loop semimetals — •Assem Alassaf[1], László Oroszlány[2], and János Koltai[3] — [1]Department of Physics of Complex Systems, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/A, 1117 Budapest, Hungary — [2]Department of Physics of Complex Systems, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/A, 1117 Budapest, Hungary; MTA-BME Lendület Topology and Correlation Research Group, Budafoki út 8., H-1111 Budapest, Hungary — [3]Department of Biological Physics, ELTE Eötvös Loránd University, Pázmány Péter sétány 1/A, 1117 Budapest, Hungary

in this paper, we establish a connection between the bulk topological structure and the magnetic properties of drumhead surface states of nodal loop semimetals. We identify the magnetic characteristics of the surface states and compute the system*s magnon spectrum by treating electron-electron interactions on a mean-field level. We draw attention to a subtle connection between a Lifshitz-like transition of the surface states driven by mechanical distortions and the magnetic characteristics of the system. Our findings may be experimentally verified, e.g. by spin-polarized electron energy loss spectroscopy of nodal semimetal surfaces.

MA 16: Magnonics I

Time: Tuesday 9:30–12:30 Location: EB 107

MA 16.1 Tue 9:30 EB 107

Propagating spin-wave spectroscopy in a liquid-phase epitaxial nanometer-thick YIG film at millikelvin temperatures — •Sebastian Knauer[1], Kristýna Davídková[2], David Schmoll[1,3], Rostyslav O. Serha[1,3], Andrey Voronov[1,3], Qi Wang[1], Roman Verba[4], Oleksandr V. Dobrovolskiy[1], Morris Lindner[5], Timmy Reimann[5], Carsten Dubs[5], Michal Urbánek[2], and Andrii V. Chumak[1] — [1]Faculty of Physics, University of Vienna, A-1090 Vienna, Austria — [2]CEITEC BUT, Brno University of Technology, 612 00 Brno, Czech Republic — [3]Vienna Doctoral School in Physics, University of Vienna, A-1090 Vienna, Austria — [4]Institute of Magnetism, Kyiv 03142, Ukraine — [5]INNOVENT e.V. Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

Realising large-scale integrated magnonic circuits for quantum applications requires propagating spin-wave spectroscopy in nanostructures at low temperatures. In this work, we demonstrate all-electrical spin-wave propagation in a 100 nm-thick yttrium-iron-garnet (YIG) film at temperatures down to 45mK. The extracted spin-wave group velocity and the YIG saturation magnetisation agree well with the theoretical values. We show that the gadolinium-gallium-garnet (GGG) substrate influences the spin-wave propagation characteristics only for the applied magnetic fields beyond 75mT, originating from a GGG magnetisation up to 62kA/m (45mK). Our results demonstrate that the developed fabrication and measurement methodologies enable the realisation of integrated magnonic quantum nanotechnologies at millikelvin temperatures.

MA 16.2 Tue 9:45 EB 107

Resonant excitation of vortex gyrotropic mode via surface acoustic waves — •Abbas Koujok[1], Alejandro Riveros[2], Davi R. Rodrigues[3], Giovanni Finocchio[4], Mathias Weiler[1], Abbass Hamadeh[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Escuela de Ingeniería, Universidad Central de Chile, 8330601 Santiago, Chile — [3]Department of Electrical and Information Engineering, Politecnico di Bari, 70126 Bari, Italy — [4]Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, 98166, Messina, Italy

With the increasing demand to miniaturize data processing devices while reducing power consumption and enhancing performance, magnonic circuits have been identified as a promising candidate in the framework of non-conventional computing. However, energy-efficient conversion from the magnonic to the electronic domain and vice versa remains a challenge for magnonics. Here, we propose a method of vortex core gyrotropic excitation relying solely on electric fields rather than on the flow of electric current, hence minimizing Ohmic losses resultant of Joule heating. Our method employs surface acoustic waves (SAWs) to excite vortex dynamics via inverse magnetostriction. We present an analytical model validated by micromagnetic simulations to demonstrate the ability of resonant SAWs to drive the gyrotropic motion of the vortex core. Varying the amplitude of the SAW, we can control the radius of the trajectory underwent by the vortex core.

MA 16.3 Tue 10:00 EB 107

Tunable topological magnon-polaron states and intrinsic anomalous Hall phenomena in 2D ferromagnetic insulators — •Alireza Qaiumzadeh and Jostein Kløgetvedt — QuSpin, Department of Physics, NTNU

We study magnon-polaron hybrid states, mediated by Dzyaloshinskii-Moriya and magnetoelastic interactions, in a two-dimensional ferromagnetic insulator. The magnetic system consists of both in-plane and flexural acoustic and optical phonon bands, as well as acoustic and optical magnon bands. Through manipulation of the ground-state magnetization direction using a magnetic field, we demonstrate the tunability of Chern numbers and (spin) Berry curvatures of magnon-polaron hybrid bands. This adjustment subsequently modifies two intrinsic anomalous Hall responses of the system, namely, the intrinsic thermal Hall and intrinsic spin Nernst signals. Notably, we find that by changing the magnetic field direction in particular directions, it is possible to completely suppress the thermal Hall signal while maintaining

a finite spin Nernst signal. Our finding reveals the intricate interplay between topology and magnetic ordering, offering compelling avenues for on-demand control over emergent nontrivial topological states and quantum transport phenomena in condensed matter systems by potential applications in both classical and quantum information technology.

MA 16.4 Tue 10:15 EB 107

Spatiotemporal magnon propagation dynamics in ultrathin iron garnets — •Volker Wiechert, Julian Bär, Moritz Cimander, Maurus Mrotzek, and Davide Bossini — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Recently, ferrimagnetic iron garnets have emerged as a potential material system to study the dynamics and manipulation of spin waves on their fundamental temporal and spatial scales [1]. Today's manufacturing processes also make it possible to produce nanometer-thick layers with variable rare-earth doping that exhibit new dynamic properties [2].

Until now, the spatiotemporal control of magnon propagation on fundamental scales has been barely addressed and, almost exclusively, in a linear spin wave regime. We set out to tackle spatiotemporal magnon dynamics in a nonlinear regime with an all-optical approach. The high tunability of the laser system also allows the individual sublattices of the ferrimagnet to be probed and provides further insights into the dynamics of these compounds [3]. Preliminary measurements of local spin dynamics in Gd-doped iron garnet already displayed nonlinear spin dynamics [4].

[1] T. Satoh et al., *Nat. Photon.* **6**, 662 (2012). [2] L. Soumah et al., *Phys. Rev. Lett.* **127**, 077203 (2021) [3] M. Deb et al., *J. Phys. D: Appl. Phys.* **45**, 455001 (2012) [4] V. Wiechert et al., *in preparation*

MA 16.5 Tue 10:30 EB 107

Femtosecond coupled spin and charge dynamics in an antiferromagnet — •Moritz Cimander, Volker Wiechert, Julian Bär, and Davide Bossini — Universität Konstanz, Konstanz, Germany

The research field adressing spin dynamics in magnets has gained recently a remarkable popularity. Especially antiferromagnets are of interest in view of high magnon frequencies in the THz regime, the lack of stray field and aboundant availibility in nature[1]. However fundamental questions regarding the control of coherent spin dynamics and a possible coupling of charges have still to be solved.

As previously demonstrated, coherent magnons can be excited in a nickel oxide single crystal via optical pumping of an exciton-magnon transition[2]. However, the resulting dynamics of the electronic system has not yet been explored. In particular, we set out to establish the possibility of a coupling between the photoinduced coherent magnons and the optical properties of the electronic system.

For this purpose, we developed a cryogenic magneto-optical pump-probe spectrometer in the VIS-NIR region. This apparatus enabled the detection of optical and magneto-optical dynamics, triggered by resonant and off-resonant excitation of the exciton-magnon and allows the coherent manipulation of the transient transmissivity by magnons. A systematic investigation of the observed effect as a function of several experimental parameters will be presented and discussed.

[1] M. B. Junglfleisch. et al.: Phys. Lett. A 382, 865 (2018)
[2] D. Bossini et al.: Phys. Rev. Lett. 127, 077202 (2021)

MA 16.6 Tue 10:45 EB 107

Unraveling the magnon-phonon hybridization in Fe3GeTe2 — •Namrata Bansal[1], Qili Li[1], Paul Nufer[1], Lichuan Zhang[2], Amir Abbas Haghighirad[3], Yuriy Mokrousov[2,4], and Wulf Wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Peter Gruenberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1) Forschungszentrum, Juelich GmbH, D-52425 Juelich — [3]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [4]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

We explore the dynamic interplay between magnons and phonons in Fe3GeTe2 (FGT) single crystals using inelastic scanning tunneling spectroscopy (ISTS) at 35 mK. ISTS has been widely employed to investigate the inelastic scattering of hot carriers off phonons or magnons, and in our study, we reveal magnon-phonon coupling in FGT. We find a significant interaction between magnons and acoustic phonons, giving rise to the formation of van Hove singularities through avoided level crossings and the hybridization of magnon and phonon bands within the material. We identify the hybridization points in the dispersion relations and contrast their energies with density functional theory calculations. These discoveries provide a foundation for tailoring the dynamic magnon-phonon coupling properties in two-dimensional materials.

Reference: Bansal, et al., arXiv: 2308.10774 (2023)

15 min. break

MA 16.7 Tue 11:15 EB 107

Fine-Tuning Spin-Wave Transducers for Improved Efficiency and Sensitivity — •Felix Kohl, Björn Heinz, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Current research in magnonics is addressing the transition from potential feasibility to functional applicability, with a particular focus on improving the efficiency of integrated spin-wave transducers, including spin-wave excitation as well as detection. Although spin-wave transducers relying on spin-wave excitation by dynamic Oersted fields are widely used, their inefficiency raises the need for significant enhancements. In a comprehensive study, we evaluate the achieved levels of efficiency under consideration of various key parameters such as the shape of the transducer antenna, magnetic material properties and spin-wave dispersion. By means of propagating spin-wave spectroscopy we measure spin-wave transmission and interpret results, providing valuable insights into the system's behavior. The acquired results, coupled with theoretic modelling of the systems, serve as a guiding framework for the optimization of transducers. Utilizing this framework, optimized transducers are fabricated and tested for their efficiency. This work represents a crucial step towards realizing the full potential of magnonics in practical applications. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 16.8 Tue 11:30 EB 107

Investigation of parallel parametric signal amplification in YIG nanostructures — •Akira Lentfert[1], Björn Heinz[1], David Breitbach[1], Carsten Dubbs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

In the pursuit of advanced information processing beyond traditional CMOS technologies, various magnonic circuits and devices such as magnon transistors, majority gates, and half adders have been developed. However, for an extended magnonic network, a phase-conserving amplification of spin waves is required. One of the candidates is the use of the parallel parametric pumping process. A phase-conserving signal amplification in metallic waveguides has already been demonstrated in previous works. In this work, we focus on the phase dependence of the parallel parametric pumping processes in Damon-Eschbach (DE) geometry in yttrium iron garnet (YIG) nanowaveguides. Due to the low spin-wave damping in YIG, other damping mechanisms such as radiative losses have a significant impact on the pumping processes. Time-resolved micro-focused Brillouin light scattering spectroscopy is used to obtain the pumping threshold and to study the amplification of short spin-wave pulses. This project has been supported by the EU Horizon research and innovation program within the SPIDER project (No. 101070417) and by DFG (TRR 173-268565370: Spin+X).

MA 16.9 Tue 11:45 EB 107

Magnon spin capacitor — •Pieter M. Gunnink[1], Tim Ludwig[2], and Rembert A. Duine[2,3] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]Institute for Theoretical Physics and Center for Extreme Matter and Emergent Phenomena, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands — [3]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

We show that a magnon spin capacitor can be realized at a junction between two exchange coupled ferromagnets [Gunnink et al., arXiv:2310.09064]. In this junction, the buildup of magnon spin over the junction is coupled to the difference in magnon chemical potential, realizing the magnon spin analogue of an electrical capacitor. We analyse the junction in detail by considering spin injection and detection from normal metal leads, the tunnelling current across the junction and magnon decay within the ferromagnet, showing that such a structure realizes a magnon spin RC circuit. Choosing platinum and yttrium iron garnet as the normal metal and ferromagnet, we numerically calculate the RC time, which ranges from picoseconds to microseconds, depending on the area of the junction. We therefore conclude that the magnon spin capacitor has clear experimental signatures and could directly be of use in applications.

MA 16.10 Tue 12:00 EB 107

Giant Surface Acoustic Wave Nonreciprocity in CoFeB/Ru/CoFeB Synthetic Antiferromagnets — •Matthias Küss[1], Stephan Glamsch[1], Mariam Hassan[1], Yannik Kunz[1], Andreas Hörner[1], Mathias Weiler[2], and Manfred Albrecht[1] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Surface acoustic waves (SAWs) have made their way into many everyday devices. These "nano earthquakes" can be efficiently launched and detected on piezoelectric substrates with periodic metallic gratings. Resonant coupling of SAWs with spin waves (SWs) is the basis for an energy-efficient approach towards SW manipulation. In addition, magnetoacoustic interaction affects the properties of the SAW, which in turn can be used to devise new types of microwave devices.

Here, we investigate the SAW-SW interaction in a synthetic antiferromagnet (SAF) composed of two ferromagnetic layers separated by a thin nonmagnetic spacer layer. The low-frequency SW mode shows a large nonreciprocal SW dispersion $f(+k) \neq f(-k)$. Because of efficient coupling between this SW mode and the SAW, we observe large nonreciprocal SAW transmission in the piezoelectric/SAF hybrid device. We demonstrate that the SAW transmission nonreciprocity can be optimized to be giant (> 100 dB) in CoFeB/Ru/CoFeB SAFs made out of low-damping CoFeB magnetostrictive layers, which holds potential for the realization of acoustic isolators [M. Küß et al., ACS Appl. Electron. Mater. 5, 5103 (2023)].

MA 16.11 Tue 12:15 EB 107

Nonlinear erasing of propagating spin-wave pulses — •David Breitbach[1], Moritz Bechberger[1], Björn Heinz[1], Bert Lägel[1], Carsten Dubs[2], Roman Verba[3], Abbass Hamadeh[1], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany — [3]Institute of Magnetism, Kyiv 03142, Ukraine

Nonlinear phenomena are key for magnon-based information processing and have led to the realization of numerous building blocks for spin-wave-based computing. The nonlinear interaction between two spin-wave signals requires their spatio-temporal overlap which can be challenging for directional processing devices. We study a nearly compensated, gallium-substituted-YIG film. This system exhibits an exchange-dominated dispersion relation and PMA, resulting in a particularly wide range of group velocities compared to YIG. Using time-resolved BLS microscopy, we demonstrate the excitation of two delayed spin-wave pulses at different frequencies from the same source, where the delayed pulse catches up with the previously excited pulse and outruns it due to its higher group velocity. Depending on the excitation power, the delayed pulse nonlinearly interacts with the first pulse, hindering its propagation and erasing the prior signal. Our work achieves a temporal logic operation with potential application for inhibitory neuromorphic functionality. This research is funded by the DFG - Project No. 271741898, by TRR 173-268565370 (B01), and by the ERC Grant No. 101042439 'CoSpiN'.

MA 17: Computational Magnetism II

Time: Tuesday 9:30–12:45 Location: EB 202

MA 17.1 Tue 9:30 EB 202

Rational design of RE-free magnets from first principles via Bayesian optimisation — •Fabian Eilers, Stephan Erdmann, Halil Ibrahim Sözen, and Thorsten Klüner — Institute of Chemistry, Carl-von-Ossietzky University of Oldenburg, D-26129 Oldenburg, Germany

The design of new rare-earth-free permanent magnetic materials to replace the powerful, but critically limited, rare earth-based magnets remains a a major challenge for the scientific community. Here we report on the rational design of new RE-free magnets using Bayesian optimisation. We attempt to improve the magnetic properties and phase stability of Fe2P-based magnetic materials by optimising the chemical composition and the lattice configuration of the unit cell. This problem involves global optimisation in a high configuration space. Bayesian optimisation can be used as a sequential design strategy to effectively explore this high configuration space. In an active learning approach, new trials are generated by sampling based on the expected improvement of the Gaussian process surrogate model. Trial evaluation is then performed via first-principles calculations using the Korringa-Kohn-Rostoker and Coherent Potential Approximation (KKR-CPA) method.

MA 17.2 Tue 9:45 EB 202

Efficient Implementation of the Minimum Mode Following Method for magnetic systems — •Hendrik Schrautzer[1,2], Moritz Sallermann[1,3,4], Stefan Heinze[2], Hannes Jónsson[1], and Pavel F. Bessarab[1] — [1]University of Iceland, Reykjavik, Iceland — [2]Christian-Albrechts-University, Kiel, Germany — [3]Forschungszentrum Jülich and JARA, Jülich, Germany — [4]RWTH Aachen University, Aachen, Germany

Magnetic systems hosting topological textures have been of great technological and fundamental interest in recent years. Identifying the lifetime of metastable states, predicting hitherto unknown states, and computing their kinetics are essential tasks [1]. Identifying first-order saddle points on the energy surface is paramount in this context, and the potential for identifying magnetic systems through the implementation of the Minimum Mode Following approach is significant [2]. However, the main computational challenge lies in determining the eigenmodes of the Hessian, which means that embedding these methods in adaptive kinetic Monte Carlo simulations has not yet been achievable. We introduce an efficient implementation of a Riemannian optimization of the Rayleigh Quotient on the Grassmann manifold, which achieves high accuracy determination of extremal eigenmodes without requiring explicit second-order Hessian information. The efficiency of the method is demonstrated by computing various transitions in a complex multistable skyrmionic system.

1: F. Muckel et al., Nat. Phys. 17.3 (2021):395-402
2: G. P. Müller et al., Phys. Rev. Lett. 121.19 (2018):197202

MA 17.3 Tue 10:00 EB 202

Mixed valence nature of the Ce 4f state in $CeCo_5$ — •Ruiwen Xie and Hongbin Zhang — Group of Theory of Magnetic Materials, Technical University of Darmstadt, Darmstadt, Germany

Cerium-based intermetallics are currently attracting much attention as highly promising alternatives to conventional permanent magnets that contain a scarce rare earth element like neodymium. Furthermore, the mixed valency nature of Ce, as unveiled by experimental XPS and BIS spectra, broadens the scope for another intriguing field of investigation. Here we apply a charge fully self-consistent approach combining density functional theory and dynamical mean-field theory (DFT+DMFT) to investigate the magnetization and electronic structure of the $CeCo_5$ system. In addition, the Ce-4f valence state fluctuations are evaluated and compared within pristine $CeCo_5$ and Cu-doped $CeCo_5$. Contrasting behaviours of Cu doping effects on the two Wyckoff positions of Co are found, which is expected to contribute to the experimentally reported nonmonotonic change of the magnetic anisotropy with increasing Cu alloying content in $Ce(Co_{1-x}Cu_x)_5$ alloys.

MA 17.4 Tue 10:15 EB 202

Is the ground state of Anderson's impurity model a recurrent neural network? — •Jonas B. Rigo[1] and Markus Schmitt[1,2] — [1]Forschungszentrum Jülich, Institute of Quantum Control (PGI-8), D-52425 Jülich, Germany — [2]University of Regensburg, 93053 Regensburg, Germany

When the Anderson impurity model (AIM) is expressed in terms of a Wilson chain it assumes a hierarchical Renormalization group structure that translates to a ground state with features like Friedel oscillations and the Kondo screening cloud [1]. Recurrent neural networks (RNNs) have recently gained traction in the form of Neural Quantum

States (NQS) ansätze for quantum many body ground states and they are known to be able to learn such complex patterns [2]. We explore RNNs as an ansatz to capture the AIM's ground state for a given Wilson chain length and investigate its capability to predict the ground state on longer chains for a converged ground state energy.

[1] Affleck, Ian, László Borda, and Hubert Saleur. "Friedel oscillations and the Kondo screening cloud." Physical Review B 77.18 (2008): 180404.

[2] Hibat-Allah, Mohamed, et al. "Recurrent neural network wave functions." Physical Review Research 2.2 (2020): 023358.

MA 17.5 Tue 10:30 EB 202

High-throughput calculation of magnetic exchange interactions using DFT — •Jan Priessnitz and Dominik Legut — IT4Innovations, VSB-TU Ostrava, Ostrava, Czechia

Ab-initio calculation of magnetic properties is an invaluable tool in development of novel magnetic materials. Magnetism in these materials can often be modeled using the classical Heisenberg model, with exchange interaction being the most significant term, determining the ground state magnetic ordering as well as critical temperature, magnon spectrum, etc. Knowing the exchange interactions is a prerequisite for larger-scale spin-dynamic or micromagnetic calculations.

Exchange interactions are usually calculated via density functional theory (DFT), either through energy variation of the ground state (Green's functions), or by calculating the total energies of multiple magnetic configurations and fitting them into the Heisenberg model Hamiltonian. Neither method is completely foolproof, limiting the high-throughput use case.

In this talk, I'm going to focus on the total energy method, presenting a new approach for selecting a suitable set of excited magnetic configurations, including an algorithm that can efficiently traverse the exponentially-growing magnetic configuration space. This improvement allows us to use the total energy method even in otherwise difficult cases, e. g., calculating long-range interactions in metallic systems.

Furthermore, I'll introduce OstravaJ, a Python package that fully automates the exchange interaction calculation, employing in principle any non-collinear electronic structure DFT code, e.g. VASP.

MA 17.6 Tue 10:45 EB 202

Machine learning-based prediction of transfer integrals in undoped cuprates — •Denys Kononenko[1], Ulrich K. Rössler[1], Jeroen van den Brink[1,2], and Oleg Janson[1] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, 01069, Germany — [2]Institute for Theoretical Physics, TU Dresden, Dresden, 01069, Germany

Undoped cuprates represent an abundant class of magnetic insulators characterized by a complex interplay of chemistry and quantum fluctuations, resulting in diverse magnetic behaviors. Comprehending the magnetism in these materials requires understanding the underlying spin model.

Antiferromagnetic superexchange is the dominant magnetic coupling in cuprates which is estimated through electronic transfer integrals, computed using density functional theory (DFT) within the Wannier basis. However, these calculations are computationally cumbersome. We present an alternative approach based on Artificial Neural Networks (ANN) trained on high-throughput DFT calculations. The ANN predicts transfer integrals solely based on the crystal structure, offering a more efficient and less computationally demanding method. Descriptors within the ANN model capture spatial configuration and the chemical composition of the local crystalline environment.

The ANN model is a powerful tool for predicting transfer integrals and rapidly screening the relevant spin model in undoped cuprates. This development opens new avenues for designing and exploring novel materials with tailored magnetic properties.

15 min. break

MA 17.7 Tue 11:15 EB 202

Deep learning of phase transitions for quantum spin chains from correlation aspects — •Ming-Chiang Chung — National Chung-Hsing University, Taichung, Taiwan

Using machine learning (ML) to recognize different phases of matter and to infer the entire phase diagram has proven to be an effective tool given a large dataset. In our previous proposals, we have successfully explored phase transitions for topological phases of matter at low dimensions either in a supervised or an unsupervised learning protocol with the assistance of quantum information related quantities. In this work, we adopt our previous ML procedures to study quantum phase transitions of magnetism systems such as the XY and XXZ spin chains by using spin-spin correlation functions as the input data. We find that our proposed approach not only maps out the phase diagrams with accurate phase boundaries, but also indicates some new features that have not been observed in the field of machine learning before. In particular, we define so-called relevant correlation functions to some corresponding phases that can always distinguish between those and their neighbors.

[1]Y. H. Tsai, M.Z. Yu, Y.H. Hsu, and M.C. Chung, Phys. Rev. B 102, 054512 (2020). [2]Y.H. Tsai, K.F. Chiu, Y.C. Lai, K.J. Su, T.P. Yang, T.P. Cheng, G.Y. Huang, and M.C. Chung, Phys. Rev. B 104, 165108 (2021). [3]Ming-Chiang Chung, Guang-Yu Huang, Ian P. McCulloch, and Yuan-Hong Tsai, Phys. Rev. B 107, 214451 (2023)

MA 17.8 Tue 11:30 EB 202

Translationally Invariant Formalism for the Computation of Orbital Magnetization — •Seung-Ju Hong and Cheol-Hwan Park — Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

The computation of orbital magnetization [1,2] is implemented in various codes, such as Wannier90 and Wannierberri. However, for an accurate computation, there are some remaining practical issues. One of the issues is the violation of translational invariance in the finite difference formula, that is, the results change under lattice vector translation of selected atoms or arbitrary translation of the whole system.

Recently, a translationally invariant formalism for the position matrix elements was developed [3]. In this talk, we will discuss the extension of translational invariance of the other Wannier matrix elements needed for the computation of orbital magnetization. The results show that the convergence is much better with the translationally invariant formulae and, thus, demonstrate that the use of translationally invariant formalism is necessary for the accurate computation of orbital magnetization.

[1] T. Thonhauser, Davide Ceresoli, David Vanderbilt, and R. Resta, Phys. Rev. Lett. 95, 137205 [2] M. G. Lopez, David Vanderbilt, T. Thonhauser, and Ivo Souza, Phys. Rev. B 85, 014435 [3] J.-M. Lihm, M. Ghim, and C.-H. Park, *Accurate calculation of position matrix elements for Wannier interpolation, Part 1: translational invariance,* Wanner 2022 Developers Meeting, Trieste, Italy (2022). https://indico.ictp.it/event/9851/

MA 17.9 Tue 11:45 EB 202

Kondo cloud of a partially screened impurity coupled to s-wave superconductor — •Anand Manaparambil[1], Catalin Pascu Moca[2,3], Gergely Zarand[2], and Ireneusz Weymann[1] — [1]Adam Mickiewicz University, Poznan, Poland — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]University of Oradea, Oradea, Romania

Magnetic impurities coupled to a band of conduction electrons generate a many-body correlated state known as the Kondo state. The correlations in the Kondo state extend to large length scales compared to the size of the impurity. In general, the Kondo cloud has been predicted to extend up to micrometers in size and recent experiments have confirmed the presence of such large screening clouds. In the presence of superconducting correlations, such screening clouds have been shown to exist even outside the Kondo phase. In this work, we study a large spin Kondo model coupled to an s-wave superconductor. We show that there exists an underscreened Kondo doublet to an unscreened triplet phase transition according to the dominant energy scale. We observe different behaviors of the screening in both of the phases predicted analytically by the renormalized perturbation theory(RPT) and confirmed numerically using the Numerical Renormalization Group(NRG) methods. The spatial extension of the correlations estimated from the equal-time spin-spin correlation function calculated using the Density Matrix Renormalization Group (DMRG) corroborates the presence of screening clouds in both phases.

MA 17.10 Tue 12:00 EB 202

Ab-initio study of x-ray circular dichroism in chiral solids: disentangling magnetic and natural cross-sections — •Alberto Marmodoro[1,2], Ondrej Sipr[1,2], Sergiy Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics (FZU), AS CR Prague, Czech Republic — [2]New Technologies Center (NTC), University of West Bohemia, Plzen, Czech Republic — [3]Ludwig Maximilians University (LMU), Munich, Germany

Circular dichroism in x-ray absorption (XCD), i.e. the different cross-section for a left or right circularly polarized beam, can arise from a variety of mechanisms.

Ferromagnetic order leads to a magnetic signal (XMCD) which mainly arises from dipole-allowed transitions and which follows a well-known cosine dependence with respect to azimuthal angle between beam and magnetic moments.

Even in the absence of atomic magnetic moment, a chiral arrangement of the atoms lead among other chirality induced spin-selectivity effects (CISS) to a "natural" signal (XNCD) [1-2], which involves instead higher order terms in electron-photon interaction and which also follows a different angular dependence.

We use fully-relativistic multiple scattering / Green's function methods (KKR-GF) and density functional theory (DFT) plus enhancements for core-hole effects, in order to numerically study this phenomenology in e.g. Strukturbericht B20 compounds, and to offer some predictions for the different impact of finite temperature effects [3] onto the two above components of XCD.

MA 17.11 Tue 12:15 EB 202

Automating ab initio modeling applied to muon spin rotation and relaxation spectroscopy — •Miki bonacci[1], Ifeanyi John Onuorah[2], Roberto De Renzi[2], Giovanni Pizzi[1], and Pietro Bonfa'[2] — [1]Paul Scherrer Institut, Switzerland — [2]Universita' degli studi di Parma, Italy

Muon spin spectroscopy is a precise experimental tool used to characterize several physical phenomena, from magnetic to superconducting phases [1]. For an accurate characterization, first-principles simulations are crucial to supply experimental measurements with an accurate prediction of muon resting sites in samples and the associated magnetic fields [2]. Furthermore, in silico characterizations readily discern cases where the muon probe itself plays a significant role [3]. These simulations, requiring deep expertise, are thus not easily accessible by non-expert users. Here, we propose the full automation of ab-initio muon characterization in crystalline solids. The predictive power of DFT is exploited by means of ad-hoc workflows implemented in AiiDA [4], encoding all the expertise needed to perform accurate computational muon spectroscopy. A user-friendly graphical interface, embedded in the AiiDAlab platform [5], is demonstrated, offering an intuitive means to conduct muon simulations routinely alongside experiments. We conclude by validating some well-known cases to demonstrate the predictive power of our simulations.

MA 17.12 Tue 12:30 EB 202

Energy-efficient control of magnetic states — Mohammad Badarneh[1], Grzegorz Kwiatkowski[1], and •Pavel Bessarab[1,2] — [1]Science Institute, University of Iceland, Reykjavik, Iceland — [2]Linnaeus University, Kalmar, Sweden

Control of magnetization switching is critical for the development of novel technologies based on magnetic materials. Transitions between magnetic states can follow various pathways which are not equivalent in terms of energy consumption and duration. In this study, we propose a general theoretical approach based on the optimal control theory to design external stimuli for efficient switching between target magnetic states. The approach involves calculation of optimal control paths (OCPs) for the desired change in the magnetic structure. Following an OCP involves rotation of magnetic moments in such a way that the strength of the external stimulus is minimized, but the system's internal dynamics is effectively used to aid the switching. All properties of the control pulses including temporal and spatial shape can be derived from OCPs in a systematic way. Various applications of OCP calculations are presented, including energy-efficient switching of a nanomagnet by means of external magnetic field [1] or electric current [2], spin-wave assisted magnetization reversal in nanowires [3], and optimal skyrmion motion in synthetic antiferromagnets.

[1] G.J. Kwiatkowski et al., Phys. Rev. Lett. 126, 177206 (2021).
[2] S.M. Vlasov et al., Phys. Rev. B 105, 134404 (2022).
[3] M.H.A. Badarneh et al., Nanosyst. Phys. Chem. Math. 11, 294 (2020).

MA 18: Magnetic Imaging and Sensors I

Time: Tuesday 9:30–13:00 Location: EB 301

MA 18.1 Tue 9:30 EB 301

Curvature-induced magnetic field generation in 3D nanostructures — •Sandra Ruiz-Gomez[1], Pamela Morales-Fernandez[1], Aurelio Hierro[2], Amalio Fernandez-Pacheco[3], and Claire Donnelly[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187, Dresden, Germany — [2]Depto. Física, Universidad de Oviedo, 33007 Oviedo, Spain — [3]Institute of Applied Physics, TU Wien, 1040 Vienna, Austria

Exploring three-dimensional nanomagnetic systems with unconventional spin textures opens the door to explore new magnetic phenomena. The impact of curvature on magnetic domain wall dynamics holds promise for new physics and functionalities. However, harnessing these effects requires an understanding of the fundamental properties and behaviour.

In the past few years, insight into the magnetisation configuration of three dimensional magnetic nanostructures has been achieved through developments in nanoscale magnetic tomography. However, many of these approaches primarily focus on large-scale facility of transmission electron microscopy-based methods, which are not always easily accessible. In our study, we demonstrate the feasibility of utilizing a magnetic force microscope (MFM) a standard lab-based technique, to gain insight into the magnetic behaviour of complex curved 3D nanostructures. In this way, not only are we able to identify and track the presence of magnetic textures such as domain walls but, by harnessing our sensitivity to the magnetic field, we map the generation of magnetic stray field due to local curvature-gradients in our nanostructures.

MA 18.2 Tue 9:45 EB 301

Failure Analysis and Characterization of Microwave Fields using a Scanning NV Microscope — •Bjorn Josteinsson, Andrea Morales, Gabriel Puebla Hellmann, Jan Rhensius, and Simon Josephy — QZabre, Zurich, Switzerland

Imaging of nano-meter scale current flows and microwave fields is crucial for failure analysis and verification in microchip and waveguide design. Scanning NV (Nitrogen-Vacancy) is an ideal candidate for measurements of such devices, as it has both high sensitivity and high spatial resolution at ambient conditions. To measure nano-scale currents, ac quantum sensing techniques are employed, achieving a resolution of a few tens of nanometers and resolving current densities as low as 40 nA/um. For the characterization of microwave fields, such as those from waveguides and ion-traps, we measure the Rabi rate of the NV. This involves selecting a qubit from the NV's triplet state and tuning its transition frequency to match the frequency of the device under test, achieved by applying an external magnetic bias field. The microwave emission from the device drives Rabi oscillation of the NV, and the oscillation rate directly indicates the microwave field's strength. We show how such measurements yield a three-dimensional microwave field map over a coupled waveguide using a commercial scanning NV system.

MA 18.3 Tue 10:00 EB 301

High-resolution nanoscale NMR for arbitrary magnetic fields — •Rouven Maier[1], Cheng-I Ho[2], Jonas Meinel[1], Vadim Vorobyov[1], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Germany — [2]Instititue of Organic Chemistry, University of Stuttgart, Germany

Nuclear magnetic resonance (NMR) spectroscopy poses one the most widely used spectroscopic techniques of modern times, with applications ranging from the serialized analysis of chemical structures at the molecular level to tissue imaging in clinical applications. However, the inherent insensitivity of conventional NMR spectroscopy prevents its use in studies of nanoscopic systems. By increasing the sensitivity by several orders of magnitude, nanoscale NMR spectroscopy based on the nitrogen vacancy (NV) center in diamond as quantum sensor has emerged as a promising research subject. Although recent developments of innovative NV-NMR detection schemes, such as the quantum-heterodyne (Qdyne) detection protocol enable high spectral resolutions, these schemes are inherently not applicable at high magnetic fields, to further improve the resolution and measurement times. Here we present a high-field compatible extension of the Qdyne measurement scheme by combining it with electron-nuclear-double-resonance (ENDOR) sequences. This approach paves the way for the application of NV-NMR spectroscopy in nano-scale studies of biomolecules and materials attached to the diamond surface.

MA 18.4 Tue 10:15 EB 301

Revealing the three-dimensional nature of the field-driven movement of magnetic topological defects — •Marisel Di Pietro Martínez[1], Luke Turnbull[1], Jeffrey Neethi Neethirajan[1], Max Birch[2], Simone Finizio[3], Jörg Raabe[3], Anastasios Markou[1], Edouard Lesne[1], María Vélez[4,5], Aurelio Hierro-Rodríguez[4,5], and Claire Donnelly[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]RIKEN Center for Emergent Matter Science (CEMS) Wako, Japan — [3]Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland — [4]Departamento de Física, Universidad de Oviedo, Oviedo, Spain — [5]CINN (CSIC-Universidad de Oviedo), El Entrego, Spain

In recent years, there has been a surge of interest in expanding from two (2D) to three dimensional (3D) magnetic systems. This extra dimension brings new magnetic textures, which promise applications in information storage and processing. The experimental detection and 3D visualization of nanometric magnetic textures has been made possible by the development of 3D X-ray magnetic tomography. Here we have combined 3D soft X-ray magnetic imaging with the application of in situ magnetic fields, allowing us to draw a connection between the motion of 2D topological defects in magnetic thin films, and their underlying 3D magnetic structure. These advances establish the necessary capabilities for the study of the behavior of topological textures in 3D, opening the door to insights into the field-driven behavior of buried three-dimensional magnetic textures.

MA 18.5 Tue 10:30 EB 301

Mapping magnetic auto-oscillations using a single quantum sensor — •Toni Hache[1], Anshu Anshu[1], Frank Thiele[2], Gunther Richter[2], Rainer Stöhr[3], Klaus Kern[1,4], Jörg Wrachtrup[1,3], and Aparajita Singha[1,5] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]Max Planck Institute for Intelligent Systems, Stuttgart — [3]3rd Institute of Physics and Research Center SCoPE, University of Stuttgart — [4]Institute de Physique, École Polytechnique Fédérale de Lausanne — [5]IQST, University of Stuttgart

Magnetic auto-oscillations in nanoscale devices (∼100 nm) have garnered significant interest in recent years as candidates for microwave or spin-wave sources and neurons in neuromorphic computing. They are generated during the interaction of spin currents with the magnetization in ferromagnetic materials via the spin-transfer torque. However, auto-oscillation modes can't be resolved with widely used laser-scanning methods. Furthermore, without additional effort they can't be measured with any stroboscopic technique. The mode formation has to be better understood to improve output power and coherence of such devices. Here we demonstrate high resolution spatial mapping of magnetic auto-oscillations with scanning nitrogen-vacancy (NV) center magnetometry. Our measurement relies on the synchronization of the microwave field generated by the auto-oscillation to the NV-spin resonance. The lateral extension of the auto-oscillation modes is obtained by measuring the intensity of the photoluminescence of the NV center which is low wherever the auto-oscillation mode is present.

MA 18.6 Tue 10:45 EB 301

Determination of Magnetic Symmetries by Electron Diffraction — •Oleksandr Zaiets[1,2], Carsten Timm[3], Jan Rusz[4], Subakti Subakti[1], and Axel Lubk[1,5] — [1]Leibniz Institute for Solid State and Materials Research Dresden, Dresden, Germany — [2]Faculty of Physics, TU Dresden, Dresden, Germany — [3]Institute of Theoretical Physics, TU Dresden, Dresden, Germany — [4]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [5]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany

It is well known that convergent beam electron-beam diffraction methods can be used to determine spatial symmetries of crystalline samples, due to the relationship between the diffraction groups (symmetry group of electron diffraction pattern) and the point group of the sample.[1] In this work we show an extension toward magnetic point groups. We give a complete mapping of magnetic point groups to corresponding diffraction groups for different crystal orientations. We conduct electron scattering simulations in order to verify the group theoretical considerations and show first experimental results.

[1] B. F. Buxton, J. A. Eades, John Wickham Steeds, G. M. Rackham, and Frederick Charles Frank. The symmetry of electron diffraction zone axis patterns. Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, 281(1301):171-194, 1976.

MA 18.7 Tue 11:00 EB 301

Novel micro-coil designs for investigations of individual magnetic nanowires — •Aniruddha Sathyadharma Prasad[1,2], Rachappa Ravishankar[1,2], Volker Neu[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]IFW Dresden — [2]TU Dresden

Iron filled carbon nanotubes (FeCNTs) have been shown to be excellent magnetic sensors for use in magnetic force microscopy (MFM)[1]. The high aspect ratio and monopole like behaviour of FeCNTs allow for performing quantitative stray field measurements of various magnetic samples. Their magnetic switching fields are as high as 400 mT, which aids in the magnetic stability while performing MFM measurements.

In this work, we present novel micro-coil designs which can generate magnetic flux densities > 600 mT localised at the nanoscale. These coils can be utilized to investigate the switching behaviour of individual nanowires and can also be used to switch the direction of the magnetic moment in FeCNT-based MFM probes. Peak fields achieved by previous micro-coil designs were in the order of tens of mT, which is insufficient for switching the FeCNTs. We overcome the limitations of the conventional micro-coil design by integrating several heat-sink structures to carry heat away from the centre of the coil. This allows for higher currents to be pushed into the coil, while keeping the local temperature below the melting point of the materials involved.

The inhomogeneous field distributions generated by the micro-coils additionally presents an opportunity to study the behaviour of magnetic nanowires in non-uniform magnetic fields.

[1] Freitag, N.H. et al. Commun Phys 6, 11 (2023).

15 min. break

MA 18.8 Tue 11:30 EB 301

Coherent x-ray magnetic imaging with 5 nm resolution — •Riccardo Battistelli[1,2], Daniel Metternich[1,2], Michael Schneider[3], Lisa-Marie Kern[3], Kai Litzius[2], Josefin Fuchs[3], Christopher Klose[3], Kathinka Gerlinger[3], Kai Bagschik[4], Christian Günther[5], Dieter Engel[3], Claus Ropers[6,7], Stefan Eisebitt[3,8], Bastian Pfau[3], Felix Büttner[1,2], and Sergey Zayko[6,7] — [1]Helmholtz-Zentrum Berlin — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg — [3]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy — [4]Deutsches Elektronen-Synchrotron (DESY) — [5]Technische Universität Berlin, Zentraleinrichtung Elektronenmikroskopie (ZELMI) — [6]Max Planck Institute for Multidisciplinary Sciences — [7]4th Physical Institute, University of Göttingen — [8]Technische Universität Berlin, Institut für Optik und Atomare Physik

Soft x-ray microscopy plays an important role in modern spintronics, but the resolution of most x-ray magnetic imaging experiments is above 10 nm, limiting access to fundamental length scales. Here, we demonstrate x-ray magnetic microscopy with 5 nm resolution by combining holography-assisted coherent diffractive imaging with heterodyne amplification of the weak magnetic signal. The gain in resolution and contrast allows direct access to key magnetic properties, including domain wall profiles and the position of pinning sites.

MA 18.9 Tue 11:45 EB 301

Three-dimensional integrated circuit activity imaging using quantum defects in diamond — •Marwa Garsi[1], Rainer Stöhr[1], Andrej Denisenko[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany — [2]SQUTEC-TTI GmbH, 70569 Stuttgart, Germany

The continuous scaling of semiconductor-based technologies to micron and sub-micron regimes has resulted in higher device density and lower power dissipation. Many physical phenomena, such as self-heating or current leakage, become significant at such scales. An efficient way to visualise such charge transport is to image the associated magnetic fields that pass unaffected through the materials used in semiconductor devices. However, advanced non-invasive imaging technologies are limited to the two-dimensional spatial realm only, while modern integrated circuits adopt a three-dimensional architecture. Here, we use near-surface nitrogen-vacancy centres in diamond with the unique ability to detect vectorial fields on the nanoscale. We optimise the Oersted field imaging procedure and present current distribution imaging within a multi-layered microchip designed with the recent back-end-of-line (BEOL) technology [1]. Our results provide, therefore, a decisive step toward three-dimensional current mapping in technologically relevant nanoscale electronics chips [2].

[1] J. Böck et al., Proceedings of the IEEE Bipolar/BiCMOS Circuits and Technology Meeting 121 (2015).

[2] M. Garsi et al., arXiv:2112.12242 (2021).

MA 18.10 Tue 12:00 EB 301

Utilizing NV Magnetometry in Materials Research — •Hayden Binger, Young-Gwan Choi, Luke Turnbull, Claire Donnelly, and Uri Vool — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Measuring the local magnetic field has proven invaluable to the characterization of quantum materials. While there are several established techniques capable of this, challenges still remain such as low sensitivity, invasiveness, or required cryogenic temperatures. Single spin scanning magnetometry based on the Nitrogen Vacancy (NV) is a fast growing technology that provides a route to overcome these limitations, providing noninvasive nanoscale resolution of magnetic fields up to room temperature. As it combines qubit measurements with a scanning platform, it requires expertise in various fields, including optics, RF engineering, atomic force microscopy, and quantum control. With growing interest in the field, the NV platform is moving from being highly specialized to becoming accessible to the general condensed matter physicist. In this talk I will discuss the benefits and limitations of NV magnetometry and how it can be used to characterize phenomena ranging from nanoscopic magnetic domains to local current transport. Given the advantages and usability of this technique, we believe it will soon be considered a standard addition to the material researchers repertoire.

MA 18.11 Tue 12:15 EB 301

Opto-electrical approach to resolve magnetic nanostructures in ferromagnetic and antiferromagnetic thin films — •Atul Pandey[1,2], Jitul Deka[1], James m Taylor[2], Stuart s p Parkin[1], and Georg Woltersdorf[1,2] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany

We present an opto-electrical approach based on the anomalous Nernst effect (ANE) to image magnetic domain structures. For this, a focused laser beam creates a temperature gradient and the voltage due to ANE is detected. As this voltage is proportional to magnetization, a spatially-resolved measurement allows to image the domain structures and characterize magnetic properties. The spatial resolution in such an experiment is given by diffraction limited spot size of the focused laser beam, which is on the order of 300 nm for a green laser. A near-field optical microscope is utilized to make the improvement. This allows us to obtanin the resolution of 10s of nm. Traditional techniques for imaging magnetic domains rely on coupling of magnetic stray fields. Therefore, it is challenging to image domain structures in antiferromagnet due to their relatively small stray fields. Since ANE in antiferromagnets is a Berry curvature driven effect, our technique can also be used to image magnetic domains in antiferromagnets.

MA 18.12 Tue 12:30 EB 301

Ultrafast soft X-ray magnetic holography at SwissFEL — Boris Sorokin, Andre Al Haddad, Kirsten Schnorr, Joerg Raabe, and •Simone Finizio — Paul Scherrer Institut, Villigen PSI, Switzerland

X-ray imaging at synchrotrons have enabled a significant advancement in the understanding of the physics driving magnetic systems. Nevertheless, for X-ray imaging at ultrafast timescales, free-electron lasers become a necessity. In this presentation, an overview of the first results of the magnetic imaging setup recently commissioned at the Maloja endstation of the soft X-ray Athos beamline at SwissFEL (PSI, Switzerland), which is based on X-ray holography, will be given. This is a lensless imaging technique that allows the retrieval of both amplitude and phase information of the sample transmission function. Since X-ray holography is an intrinsically drift free technique and a full-field microscopy technique, it is well suited for free-electron lasers, where shot-to-shot variations render scanning microscopy techniques unbefitting. Athos beamline of SwissFEL, with its 16 Apple-X undulators, provides soft X-ray radiation with a fully controllable polarisation. This makes it particularly suitable for ultrafast X-ray magnetic imaging, where XMCD and XLD are employed as contrast mechanisms for both ferromagnetic and antiferromagnetic samples, respectively. During the commissioning phase, we demonstrated the possibility of measuring the static images of the labyrinth magnetic domain structures in thin films with perpendicular magnetic anisotropy. This is the first step towards ultrafast time-resolved soft X-ray magnetic imaging.

MA 18.13 Tue 12:45 EB 301

Non-invasive magnetic imaging and characterization of domain walls in synthetic antiferromagnets — •Ricardo Javier Peña Román[1], Dinesh Pinto[1,2], Sandip Maity[1], Fabian Samad[3,4], Olav Hellwig[3,4], Klaus Kern[1,2], and Aparajita Singha[1] — [1]Max Planck Institute for Solid State Research — [2]Institute de Physique, École Polytechnique Fédérale de Lausanne — [3]Institute of Ion Beam Physics and Material Research, Helmholtz-Zentrum Dresden-Rossendorf — [4]Insititute of Physics, Chemnitz University of Technology

Understanding the local properties of the domain wall (DW) spin textures is crucial for developing, engineering, and controlling them for potential applications in magnetic storage devices and spintronics.

For investigating DWs in synthetic antiferromagnets, here we utilize a home-built nitrogen-vacancy (NV) scanning probe microscope that combines the spatial resolution of atomic force microscopy with the exceptional magnetic sensitivity of a single NV defect in diamond as a sensor. This technique, being independent of any external perturbation, is the least-invasive scanning probe approach available at room temperature. It also allows quantitative measurements of the stray magnetic fields generated by the sample. By performing measurements with two different orientations of the AFM NV-probe, we reveal distinct fingerprints emerging from spin noise and constant magnetic stray fields from the sample. Our work opens up novel opportunities for understanding magnetic thin films quantitatively and non-invasively, along with exceptionally high magnetic sensitivity at the nanoscale.

MA 19: Surface Magnetism

Time: Tuesday 9:30–12:30 Location: EB 407

MA 19.1 Tue 9:30 EB 407

Magnetism and electronic structure of a Dy adatom on a MgO(001) substrate — •Alexander B. Shick[1,2], Eduard Belsch[1,3], and Alexander I. Lichtenstein[3,4] — [1]Institute of Physics, Czech Academy of Sciences, Na Slovance 2, Prague, CZ — [2]Weizmann Institute of Science, Rehovoth, IL — [3]Institute of Theoretical Physics, University of Hamburg, Hamburg, DE — [4]European X-Ray Free-Electron Laser Facility, Holzkoppel 4, Schenefeld, DE

The electronic structure and magnetism of individual Dy atom adsorbed on the MgO(001) substrate is investigated using the combination of DFT with the Hubbard-I approximation to the Anderson impurity model (DFT+U(HIA)). The divalent Dy^{2+} adatom in f^{10} configuration is found. The calculated XAS and XMCD spectra are compared to the experimental data. Quantum tunneling between degenerate $|J = 8.0, J_z = \pm 4.0\rangle$ states leads to formation of $|J = 8.0, J_z = 0.0\rangle$ ground state with an in-plane orientation of the magnetic moment. It explains absence of remanent magnetization in Dy adatom on the top of MgO(001) substrate. Our studies can provide a viable route for further investigation and prediction of the rare-earth single atom magnets.

Supported by Operational Programme Research, Development and Education financed by European Structural and Investment Funds and the Czech Ministry of Education, Youth and Sports (Project No. SOLID21 - CZ.02.1.01/0.0/0.0/16_019/0000760), by the GACR Grant No. 22-22322S, and by the MOIA Grant No. 714471.

MA 19.2 Tue 9:45 EB 407

The magnetic domain structure of Tb(0001)/W(110) — •Patrick Härtl, Markus Leisegang, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Rare earth metal films are known to exhibit an extremely rich magnetic behavior. In the first instance it depends on the element-specific sign and wavelength of the RKKY interaction, but details of the film preparation procedure have also been shown to influence the domain structure [1]. Here we report on an investigation of epitaxial Terbium (Tb) films on W(110) by means of spin-polarized scanning tunneling microscopy (SP-STM). Tb is a ferromagnetic metal with a Curie temperature of 221 K [2]. It exhibits a large magnetic anisotropy [3] attributed to its non-spherical $4f$ charge distribution arising from a large atomic orbital momentum ($L = 3$). The easy magnetization axis is within the basal plane along $\langle 10\bar{1}0\rangle$. Our investigation on Tb(0001) films grown on W(110) indeed shows a sixfold magnetic contrast, consistent with the expected in-plane orientation of magnetic domains and comparable to earlier studies of Dy(0001)/W(110) [4]. Thickness-dependent studies reveal that the magnetic domain sizes increases with increasing film thicknesses. Domain walls are identified as Néel walls with a width of $1.4 - 3.6$ nm.

[1] P. Härtl *et al.*, Phys. Rev. B **105**, 174431 (2022).
[2] J. E. Prieto *et al.*, Phys. Rev. B **94**, 174445 (2016).
[3] J. J. Rhyne *et al.*, J. Appl. Phys. **38**, 1379 (1967).
[4] L. Berbil-Bautista *et al.*, Phys. Rev. B **76**, 064411 (2007).

MA 19.3 Tue 10:00 EB 407

Exploring the complex magnetism of hexagonal Mn mono- and double-layers on Ir(111) — •Mara Gutzeit, Tim Drevelow, Soumyajyoti Haldar, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany

Ultrathin transition-metal films can host complex magnetic states with intriguing properties due to competing magnetic interactions. Prominent examples are antiferromagnetic (AFM) hexagonal Mn monolayers (MLs) on Re(0001) exhibiting depending on the Mn stacking either the RW-AFM or the 3Q state as the magnetic ground state [1], a double layer (DL) of Mn on the W(110) surface which holds a conical spin spiral state [2] or a Mn DL on W(001) for which the moments of the interface Mn atoms even vanish [3]. Here, employing density functional theory calculations we calculate the energy dispersion of spin spirals of both an AFM hexagonal Mn ML and a DL on Ir(111) in order to investigate their magnetic phase space. While for the ML the Néel state turns out to be energetically lowest, the situation becomes more involved for the Mn DL due to the possibility of spin spirals propagating in two interacting magnetic layers. We show that this system is characterized by a strong AFM interlayer exchange coupling giving rise to a variety of complex magnetic states that govern the low-energy regime.

[1] Spethmann *et al.* PRL **124**, 227203 (2020)
[2] Yoshida *et al.* PRL **108**, 087205 (2012)
[3] Meyer *et al.* PRR **2**, 012075(R) (2020)

MA 19.4 Tue 10:15 EB 407

Exchange engineering of a two-dimensional half-metal — •Xin Liang Tan[1,2], Arthur Ernst[3], Kenta Hagiwara[1], Ying-Jiun Chen[1,2], Claus M. Schneider[1,2], and Christian Tusche[1,2] — [1]Forschungszentrum Jülich, Peter Grünberg Institut, Jülich — [2]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [3]Institut für Theoretische Physik, Johannes Kepler Universität, A 4040 Linz, Austria

Ideal half-metals, showing conductivity only in one spin channel, would open the way to efficient spin-injection devices for spintronics. Prototypical examples of half-metals, such as Heusler alloys and complex oxides, lose their high spin polarization at the surface or when reduced to sub-nm thickness, complicating the realization of nanoscale spintronics. Here we present a bottom-up optimization pathway for the realization of a two-dimensional(2D) itinerant half-metallic iron-palladium film via direct band structure engineering. Spin-resolved momentum microscopy enables 2D spin-resolved mapping of the full Brillouin zone. A fully polarized Fermi surface, the hallmark of a half metal, was engineered via direct control of the film-film composition and alloying. The balancing acts between the exchange interaction and the spin-orbit coupling in the 2D film allow the direct tuning of electronic states. We highlight the local critical regions in momentum space contributing to the opening up of a spin gap. Layer- and spin-resolved Korringa-Kohn-Rostoker calculations with coherent potential approximation corroborate our experimental findings and reveal the interplay between the exchange and spin-orbit interactions.

MA 19.5 Tue 10:30 EB 407

Ab-initio exploration of complex magnetism of frustrated Mn films on Ag(111) surface — •Selcuk Sözeri[1,2], Nihad AbuAwwad[2,1], Amal Aldarawsheh[2,1], and Samir Lounis[1,2] — [1]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulations, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Utilizing ab-initio simulations we explore the complex magnetism emerging in antiferromagnetic Mn films deposited on Ag(111) surface. While the associated triangular lattice is prone to magnetic frustration, contradictory behaviors were reported theoretically [1,2,3] and experimentally [4]. We use the full-potential relativistic Korringa-Kohn-Rostoker Green function method to extract the magnetic exchange interaction tensors for one and two Mn monolayers grown on Ag(111). Notably, we find the free-standing Mn layer to host a spin spiraling state as the ground state, while the hybridization with the electronic states of Ag promotes the Néel state to be the lowest in energy in agreement with [4]. We extract the magnetic phase diagrams and highlight the impact of both long-range Heisenberg exchange and Dzyaloshinskii-Moriya interactions.

– Project funded by DFG (SPP 2137: LO 1659/8-1).

– [1] P. Kurz, PhD-Thesis @ RWTH-Aachen University (2000); [2] Heinze et al., Appl. Phys. A 75, 25 (2002); [2] B.R. Malonda-Boungou, et al., Comp. Cond. Mat. 16. e00368 (2019); [3] C.L. Gao, et al., PRL 101, 267205 (2008).

MA 19.6 Tue 10:45 EB 407

The Impact of Lattice Distortions on the Magnetic Stability of Single Atoms: Dy and Ho on BaO(100) — Boris V. Sorokin[1], Marina Pivetta[1], Valerio Bellini[2], Darius Merk[1], Sébastien Reynaud[1], •Alessandro Barla[3], Harald Brune[1], and Stefano Rusponi[1] — [1]Institute of Physics, EPFL, CH-1015 Lausanne, Switzerland — [2]S3-Istituto di Nanoscienze-CNR, I-41125 Modena, Italy — [3]Istituto di Struttura della Materia, CNR, Trieste, Italy

With a view to the operation as qubits and memories of surface-adsorbed single-atom magnets, there is currently a strong focus on un-

derstanding the factors determining their spin dynamics. We present our investigations of the magnetic properties of Dy and Ho atoms adsorbed on BaO(100) thin films on Pt(100) [1] and a comparison with previous results for the same two elements on MgO/Ag(100). On BaO(100), Dy shows hysteresis in magnetic fields up to ≈ 3.5 T and long spin lifetime, exceeding 300 s at 2.5 K and 0.5 T. Surprisingly, Ho shows paramagnetism, as opposed to its long spin lifetime on MgO. Our combined experimental and theoretical approach shows that the critical differences bewteen BaO(100) and MgO(100) originate from the local surface distortions induced by the adatoms: while on MgO minimal distortions involve only the closest O atoms, on BaO they affect both the closest anions and cations.

[1] B. V. Sorokin, M. Pivetta, V. Bellini, D. Merk, S. Reynaud, A. Barla, H. Brune, and S. Rusponi, Adv. Funct. Mater. 33, 2213951 (2023).

15 min. break

MA 19.7 Tue 11:15 EB 407

The quest for Single Atom Magnets: the case of Dy adatoms on $SrTiO_3$ surfaces — •Valerio Bellini[1], Stefano Rusponi[2], Marina Pivetta[2], Pietro Gambardella[3], Harald Brune[2], Carlo Carbone[4], and Alessandro Barla[4] — [1]S3-Istituto di Nanoscienze-CNR, Modena, Italy — [2]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland — [3]Department of Materials, ETH Zurich, Zurich, Switzerland — [4]Istituto di Struttura della Materia-CNR, Trieste, Italy

We present a case study of rare-earth Dy and Ho single atoms deposited on the surface of $SrTiO_3$ using a combined theoretical and experimental approach [1]. X-ray magnetic circular dichroism reveals slow relaxation of the Dy magnetization on a time scale of about 800 s at 2.5 K, unusually associated with an easy-plane magnetic anisotropy. With the help of first-principles calculations and atomic multiplet simulations we rationalise this observation in terms of the magnetic properties of the Dy atoms as a function of the occupation sites on the coexisting TiO_2 and SrO-terminated surface. Interestingly, the adsorption of Dy on the insulating $SrTiO_3$ crystal leads to the formation of a spin-polarized two-dimensional electron gas, that couples antiferromagnetically to the Dy spin moments.

[1] V. Bellini, S. Rusponi, J. Kolorenč, S. K. Mahatha, M.A. Valbuena, L. Persichetti, M. Pivetta, B. V. Sorokin, D. Merk, S. Reynaud, D. Sblendorio, S. Stepanow, C. Nistor, P. Gargiani, D. Betto, A. Mugarza, P. Gambardella, H. Brune, C. Carbone, and A. Barla. ACS Nano 16, 11182 (2022).

MA 19.8 Tue 11:30 EB 407

Bismuthene on a three-dimensional spin-structure realized in Mn/Ag(111) — •Gustav Bihlmayer[1], Chia-Ju Chen[2], Yen-Hui Lin[2], Stefan Blügel[1], and Pin-Jui Hsu[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Department of Physics, National Tsing Hua University, Hsinchu, 30013, Taiwan

Depositing Mn on a $BiAg_2$/Ag(111) surface alloy leads to the formation of a honeycomb (HC) lattice on the surface, that can be observed with scanning tunneling microscopy (STM). The HC lattice is commensurate with a p(2×2) Ag(111) unit cell and can be assigned to Bi atoms, as can be derived from comparison to density functional theory (DFT) calculations. Furthermore, in spin-polarized STM no spin-signal is visible from the HC, but islands with different spin-polarization patterns with p(2×2) periodicity are found. These patterns can be manipulated via an external magnetic field, substantiating their magnetic origin. They show similarities with a 3**Q** structure, predicted for Mn/Cu(111) [1] and observed in Mn/Re(0001) [2]. The DFT calculations confirm the stability of the 3**Q** state compared to other ground states found theoretically [3] and experimentally [4] for Mn/Ag(111). This system realizes a quantum-spin-Hall system in contact with a non-collinear three-dimensionally modulated spin structure.

[1] Ph. Kurz et al., Phys. Rev. Lett. **86**, 1106 (2001). [2] J. Spethmann et al., Phys. Rev. Lett. **124** 227203 (2020). [3] M. dos Santos Dias et al., Phys. Rev. B **83**, 054435 (2011). [4] C. L. Gao et al., Phys. Rev. Lett. **101**, 267205 (2008).

MA 19.9 Tue 11:45 EB 407

Prospecting gigantic magnetic anisotropy energies with 3d-O molecules on MgO films — •Sufyan Shehada[1,2], Manuel dos Santos Dias[3], Muayad Abusaa[2], and Samir Lounis[1,4] — [1]Peter Grünberg Institute & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Arab American University, Jenin, Palestine — [3]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom — [4]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany

Realizing stable atomic magnetic bits hinges on large out-of-plane magnetic anisotropy energy (MAE). Rau et al. detected the maximum MAE for a 3d element by inserting a Co atom on MgO(100) [1], which, however, did not show magnetic bi-stability. While simulations based on standard density functional theory (DFT) fails to capture the detected large MAE, our approach, incorporating a Hubbard U correction and spin-orbit coupling, reproduces the large MAE for a Co adatom on MgO(001). We identify the underlying mechanisms and take one step further by exploring the case of 3d-O molecules as a potential scenario to enhance the MAE while reducing the hybridization of the electronic states of the adatoms with those of the substrate in order to increase the chances for magnetic bi-stability. We investigate different structural geometries of 3d-O molecules on MgO and focus in particular on the case of molecules perpendicular to the surface.

–Work funded by (BMBF–01DH16027).

[1] Rau *et al.*, Science **344**, 988 (2014).

MA 19.10 Tue 12:00 EB 407

Complex non-collinear spin structure of a Mn double layer on Ag(111) — •Tim Drevelow and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany

Non-collinear spin structures in ultrathin transition-metal films are interesting for spintronic applications and can be stabilized by competing magnetic interactions. Higher-order exchange interactions have been shown to stabilize nontrivial spin structures such as a distorted 3Q state in a Mn monolayer on Re(0001) [1] and a conical spin spiral in a Mn double layer on W(110) [2]. The Ag(111) surface is a different type of substrate since it exhibits only a weak hybridization with magnetic overlayers and a small spin-orbit interaction such that exchange interactions should play a dominant role. Here, we present first-principles calculations for a Mn double layer on the Ag(111) surface using density functional theory. We reveal a complex three-dimensional magnetic ground state which is stabilized by higher-order exchange interactions.

[1] Haldar *et al.* Phys. Rev. B. **104**, L180404 (2021).
[2] Yoshida *et al.* Phys. Rev. Lett. **108**, 087205 (2012)

MA 19.11 Tue 12:15 EB 407

Magnetic state of rare earth atoms on NaCl films — •María Blanco-Rey[1,2,3], Fernando Delgado[4], Andrés Arnau[1,2,3], Marina Pivetta[5], Stefano Rusponi[5], and Harald Brune[5] — [1]Universidad del País Vasco UPV/EHU, Spain — [2]Donostia International Physics Center DIPC, Spain — [3]Centro de Física de Materiales MPC-CSIC-UPV/EHU, Spain — [4]Universidad de La Laguna, Spain — [5]École Polytechnique Fédérale de Lausanne EPFL, Switzerland

A combination of STM and XAS experiments shows that rare earth atoms on NaCl/Ag have $4f^n$ and $4f^{n-1}$ electronic configurations depending on the adsorption site. The NaCl film thickness determines the preferred adsorption site, which in turn defines the occupation of the 5d shell. In this contribution we show that DFT calculations for Gd and Eu ad-atoms can mimic the energetics and electronic occupation of the 6s5d shells, predicting a $4f^{n-1}$ configuration for the rare earth as a Na substitutional, an adsorption geometry that is favorable for 2ML of NaCl only. For thicker films, defect formation is hindered and only $4f^n$ species are allowed. As the rare earth atom becomes decoupled from the Ag substrate, there is a preference for adsorption sites with reduced coordination.

MA 20: Poster I

Time: Tuesday 16:30–19:00 Location: Poster A

MA 20.1 Tue 16:30 Poster A

Efficient excitation of surface-acoustic waves with impedance-matched IDTs — •Kawa Noman, Yanik Kunz, Kevin Künstle, Vitaliy Vasyuchka, and Mathias Weiler — Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau(RPTU),Kaiserslautern,Germany

Microwave filters based on surface acoustic wave (SAW) devices exhibit minimal loss and operate at high frequencies. Here we study the efficient generation and detection of high amplitude SAWs with multichromatic waveforms. This involves the use of custom-designed interdigital transducers (IDTs) that are lithographically fabricated on piezoelectric substrates such as lithium niobate (LiNbO3). We use microwave stub tuners to match the IDT impedance to the external microwave circuit to maximise the power transfer and analyse the SAW devices using a vector network analyzer. Achieving a precise 50-ohm impedance match resulted in reduced insertion loss and voltage standing wave ratio. High-amplitude SAWs can be used for non-linear magnon generation [1].

[1] M. Geilen et. al, arXiv:2201.04033 (2022).

MA 20.2 Tue 16:30 Poster A

Dynamical Renormalization of a Spin Hamiltonian via High-order Nonlinear Magnonics — •Julian Bär[1], Christoph Schönfeld[1], Lennart Feuerer[1], Alfred Leitenstorfer[1], Dominik Juraschek[2], and Davide Bossini[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel

A key question of the research field of ultrafast magnetic phenomena addresses the generation and control of magnons on fundamental timescales. Standard approaches involve resonant or non-resonant excitation of low-frequency one-magnon modes. High-frequency pairs of magnons near the edges of the Brillouin zone have also been non-resonantly induced. However, most studies disclosed spin dynamics, which are described by linear spin-wave theory. Our work utilizes a high-field laser source in the multi-THz regime to directly excite zone-edge magnons in Hematite. This pumping scheme induces an unexplored magnetic excited state. Theoretical predictions suggest that this excited state can result in strongly nonlinear magnetic phenomena. By tuning the photon energy of the mid-infrared laser, we investigate the spin dynamics induced both via resonant and non-resonant excitation of the two-magnon mode. Experimental results demonstrate coherent coupling between photo-driven high-energy magnons and zone-center modes. The photoexcitation drives the system to an extreme nonequilibrium state, significantly altering the spectrum of zone-center modes. These findings highlight the potential to manipulate the magnonic dispersion on femtosecond timescales through purely magnetic processes.

MA 20.3 Tue 16:30 Poster A

Impact of metallic magnet stray-field on propagating spin waves — •Matthias Wagner[1], Felix Kohl[1], Andrea del Giacco[2], Maria Cocconcelli[2], Silvia Tacchi[3], Riccardo Bertacco[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Department of Physics, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Department of Physics, Politecnico di Milano, Italy — [3]Istituto Officina dei Materiali (IOM) del Consiglio Nazionale delle Ricerche (CNR), Sede Secondaria di Perugia, Italy

The properties of magnonic waveguides, such as the static magnetization and the spin-wave dispersion, can be changed using external magnetic fields. For the application of magnonic devices, an energy efficient on-chip realization of a bias field is desirable that can manipulate the spin-wave properties either globally or locally. In our current feasibility study, we utilise the stray field of microstructured ferromagnets as a bias field source, investigating its effect on low damping magnonic waveguides. We employ micro-focused Brillouin light scattering spectroscopy to extract spin-wave properties and their resonance frequencies with high spatial resolution. Our experimental results are supplemented by extensive micromagnetic simulations using Mumax^3. Funding by the European Union within the HORIZON-CL42021-DIGITAL-EMERGING-01 Grant No. 101070536 M&MEMS is acknowledged.

MA 20.4 Tue 16:30 Poster A

Wide-band nonreciprocal transmission of surface acoustic waves — •Stephan Glamsch, Matthias Küss, Andreas Hörner, and Manfred Albrecht — Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Surface acoustic waves (SAWs) are utilized in everyday devices as rf-filters and sensors. However, SAWs are in general propagating reciprocally, which means that the acoustic wave properties do not change under an inversion of the propagation direction. Resonantly coupled to spin waves (SWs) in a magnetic material, the SAW transmission can instead become nonreciprocal, which holds potential for novel microwave devices, e.g. acoustic diodes. Large nonreciprocal SAW transmission in a limited frequency range close to the punctual intersection of SAW and SW dispersions have been recently demonstrated [1]. Nevertheless, nonreciprocal SAW transmission over a wide frequency band has only been theoretically predicted until now [2]. In our most recent work, we show the first experimental demonstration of a wide-band nonreciprocal SAW transmission. For that, we adjusted the SW dispersion of a CoFeB/Ru/CoFeB synthetic antiferromagnet (SAF) to match the linear dispersion of the SAW over a frequency range of $2.8\,\mathrm{GHz} < f < 7.0\,\mathrm{GHz}$. Therefore, a low loss (< 0.08 dB) mediated by SAW-SW interaction in the forward direction and large attenuation ($>$ 5dB) in the reverse direction has been achieved.

[1] M. Küß et al., ACS Appl. Electron. Mater. 5, 5103 (2023).
[2] R. Verba et al., Phys. Rev. Appl. 12, 054061 (2019).

MA 20.5 Tue 16:30 Poster A

Spin Hall driven spin-wave emission in PMA materials — •Moritz Bechberger[1], David Breitbach[1], Björn Heinz[1], Abbas Koujok[1], Bert Lägel[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Spin currents have been used extensively in the research field of magnon spintronics, as they allow to compensate the damping of magnonic systems and the generation of coherent, nonlinear magnetic auto-oscillations. However, their application as a source for propagating spin waves is very limited, given the self-confining nature of the oscillation. Here, we investigate the spin-wave emission of an auto-oscillator in a yttrium iron garnet film substituted with gallium atoms (Ga:YIG), which causes a perpendicular magnetic anisotropy. When driven to high spin-wave amplitudes for in-plane configuration, this system exhibits a positive nonlinear frequency shift due to the negative effective magnetization. We inject a spin-current into the Ga:YIG film via the spin Hall effect by applying a DC current to an adjacent platium layer and study the dynamics of the auto-oscillation with respect to the nonlinear frequency shift and a potential spin-wave emission. This research is funded by the DFG - Project No. 271741898, TRR 173-268565370 (B01), and the ERC Grant No. 101042439 CoSpiN.

MA 20.6 Tue 16:30 Poster A

Dynamics of magnon condensates in two-dimensional thermal landscapes — •Franziska Kühn[1], Matthias R. Schweizer[1], Georg von Freymann[1,2], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Fraunhofer Institute for Industrial Mathematics ITWM, Fraunhofer Platz 1, 67663 Kaiserslautern, Germany

Our work focuses on the behavior of magnon Bose-Einstein condensates (BEC) in two-dimensional artificial magnetization landscapes on the length scale of the wavelength of condensed magnons. Measurements are performed using Brillouin light scattering spectroscopy as an optical detection method of magnons. In addition, different thermal patterns in the micrometer range are imprinted onto the yttrium-iron garnet film sample through phase-based wavefront modulation. This procedure changes the temperature-dependent saturation magnetization and subsequently the effective magnetic field. Both of these effects influence the magnon spectrum to varying degrees and cause strong frequency shifts in the dispersion relation. The corresponding spatial variation of the condensate frequency, acting as an artificial potential for the BEC, affects its dynamics and propels magnon supercurrents and Bogoliubov waves. Extended two-dimensional structures are used to investigate the manipulation of the properties of magnon supercurrents, such as direction and intensity. This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-TRR 173/2-268565370 Spin+X (Project B04)

MA 20.7 Tue 16:30 Poster A

Magnon-Fluxon Dynamics in Superconductor/Ferromagnet Periodic Structures — •Björn Niedzielski and Jamal Berakdar — Martin-Luther Universität Halle-Wittenberg, Halle, Germany

Over the past decades coupled superconductor/ferromagnet (SC/FM) materials has been in the focus of research. Hybrid structures of this form are of fundamental interest and hold promising prospects for information technology. One idea is to use the stray field interaction between superconducting matter and ferromagnets to manipulate the propagation of spin waves in a magnonic wave guide. In this way a superconducting vortex lattice can act as a building block for a reconfigurable magnonic crystal with unique properties. Despite intensive research on this subject the fascinating nature of the coupled dynamics of SC/FM hybrids is not fully understood yet and only recently the first experimental evidence for magnon-fluxon-interaction has been found by Dobrovolskiy et al. (Nature Physics, 15, 477 (2019)).

Here we are aiming at understanding the magnetization dynamics of a SC/FM bilayer by simulating such a structure under realistic conditions. To this end we solve the coupled time-dependent Ginzburg-Landau equations for superconductivity and the Landau-Lifschitz-Gilbert equation for the magnetization dynamics. In accordance with the experiment we found that the presence of the vortices leads to the formation of a Bloch-like band structure in the magnonic spectrum. The width and position of these bands was observed to be highly susceptible to various system parameters like the FM geometry and structural imperfections in the vortex lattice.

MA 20.8 Tue 16:30 Poster A

Magnon polarons in an easy-plane ferromagnet — •Konrad Scharff — KIT, Karlsruhe, Deutschland

When the dispersions of spin waves and acoustic phonons cross in energy-momentum space, they tend to hybridize in the presence of a magnetoelastic coupling [1] resulting in a magnon polaron. We study the emergence of magnon polarons in the ordered phase of an easy-plane ferromagnet on a hexagonal lattice. On the level of linear spin wave theory we determine the energy spectrum and evaluate the spin structure factor.

[1] Kittel, C. Interaction of spin waves and ultrasonic waves in ferromagnetic crystals. Phys. Rev. 110, 836*841 (1958).

MA 20.9 Tue 16:30 Poster A

Magneto-Optical Investigation of Magnetoacoustic Waves in Yttrium Iron Garnet / Zinc Oxide Heterostructures — •Kevin Künstle[1], Finlay Ryburn[2], Yannik Kunz[1], Vitaliy Vasyuchka[1], Yangzhan Zhang[2], Timmy Reimann[3], Morris Lindner[3], Carsten Dubs[3], John F. Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany — [2]Clarendon Laboratory, Department of Physics, University of Oxford, Oxford, United Kingdom — [3]INNOVENT E.V. Technologieentwicklung, Jena, Germany

In recent years, the coupling of surface acoustic waves (SAWs) with spin waves (SWs) in ferromagnetic metals has emerged as a viable option for realising applications such as acoustic diodes, due to the inherently non-reciprocal SAW-SW interaction. However, the coupling of SAWs with SWs in ferrimagnetic insulators has been much less explored. We study SAWs excited by interdigital transducers made of Ti/Au deposited on a GGG/YIG thin film bilayer and covered with a piezo- electric ZnO layer. The ferrimagnetic YIG thin film acts as a source of SWs to which the SAWs can couple. We used microfocused Bril- louin light scattering (BLS) spectroscopy and vector network analyser measurements to identify the SAW characteristics. We extracted the SAW group velocity and reconstructed the non-linear SAW dispersion in the heterostructure. Furthermore, we studied the magnetic field dependent interaction of the SAWs with SWs.

MA 20.10 Tue 16:30 Poster A

Non-reciprocal phonon-magnon interaction in yttrium-iron-garnet/zinc oxide heterostructures — •Yannik Kunz[1], Julian Schüler[1], Kevin Künstle[1], Finlay Ryburn[2], Yangzhan Zhang[2], Katharina Lasinger[1], John Gregg[2], Philipp Pirro[1], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern — [2]University of Oxford

Magnon-based devices provide a promising approach for energy-efficient computation due to low intrinsic losses in materials such as yttrium-iron-garnet (YIG). However, the energy-efficient excitation of magnons in magnetic systems is challenging. A potential solution to this issue entails the exploitation of magnetoacoustic interaction for magnon generation. In this approach, surface acoustic waves (SAWs) are generated using transducers that comprise interdigital electrodes in combination with a piezoelectric thin film. The SAW can couple to magnons under conservation of energy and momentum [1]. We studied the phonon-magnon coupling in heterostructures of YIG covered by piezoelectric Zinc Oxide by performing SAW transmission measurements as a function of magnetic field magnitude and orientation. The observed magnetoelastic coupling of phonons and magnons is non-reciprocal and highly dependent on the angle between the propagation direction of the SAW and the applied magnetic field.

[1] M. Küß, M. Albrecht, and M. Weiler, Chiral Magnetoacoustics, Frontiers in Physics 10, 981257 (2022).

MA 20.11 Tue 16:30 Poster A

Spin-wave devices for hardware-based computing systems — •Jannis Bensmann[1], Dmitrii Raskhodchikov[1,2], Kirill O. Nikolaev[3], Robert Schmidt[1], Johannes Kern[1], Shraddha Choudhary[1], Vladislav E. Demidov[3], Steffen Michaelis de Vasconcellos[1], Wolfram H. P. Pernice[1,2,4], Sergej O. Demokritov[3], and Rudolf Bratschitsch[1] — [1]University of Münster, Institute of Physics and Center for Nanotechnology, 48149 Münster, Germany — [2]University of Münster, Center for Soft Nanoscience, 48149 Münster, Germany — [3]University of Münster, Institute of Applied Physics, 48149 Münster, Germany — [4]Heidelberg University, Kirchhoff-Institute for Physics, 48149 Münster, Germany

Recently, the advent of artificial intelligence systems has intensified the ever-increasing demand for computational power and driven the exploration of novel approaches to building computational systems. One possibility is hardware-based spin-wave computing. A spin wave characterizes a perturbation of the local magnetization that travels through a magnetic material. Spin waves are energy-efficient, broadband (up to THz), and can have wavelengths down to the nanometer range. We use the material yttrium iron garnet (YIG), which is known for its particularly low damping properties. To probe spin waves, we perform optical measurements such as Brillouin-light-scattering spectroscopy. For validation, we compare our experimental results with micromagnetic simulations. Utilizing nanofabrication techniques, we develop building blocks for spin-wave computing devices.

MA 20.12 Tue 16:30 Poster A

All-magnonic non-linear frequency conversion processes — •Paul Rondt, Rouven Dreyer, Chirs Körner, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

In magnonics, the phase state of spin-wave excitations in magnetically ordered materials can be exploited as a carrier of information for spin-based devices. Over the last decade, non-linear processes, such as three and four-magnon scattering, have pushed magnonics to the next level by demonstrating magnonic counterparts of electronic devices. However, the possibility of frequency up-conversion as a basic functionality for all-magnonic circuits was missing. To understand the potential use of higher-order non-linear processes, we investigated microstructured $Ni_{80}Fe_{20}$ elements by using the phase-sensitive SNS-MOKE approach as a function of element size and shape [1]. By employing this technique, we demonstrated the existence of phase-stable non-linear spin waves oscillating at odd half-integer multiples of the driving frequency and applied a phase-locking scheme [2]. Moreover, we found that for low-frequency excitations an all-magnonic frequency comb emerges spanning over six octaves, allowing to link MHz frequencies from CMOS devices to high-frequency spin-wave excitations in magnonic circuits [3].

References [1] R. Dreyer, et al., Phys. Rev. Mat. 5, 064411 (2021). [2] R. Dreyer, et al., Nat. Commun. 13, 4939 (2022). [3] C. Koerner, et al., Science 375, 1165-1169 (2022)

MA 20.13 Tue 16:30 Poster A

Micromagnetic Simulations of Spin Wave Propagation in Patterned YIG Magnonic Filters — •Luisa J. Borngräber, Stephanie Lake, Seth W. Kurfman, and Georg Schmidt — Institut für Physik, Martin Luther Universität Halle-Wittenberg, Halle, Germany

A primary objective for magnon-based computing is efficient control of spin wave propagation and long-lived magnon excitations. The former can be achieved through the use of magnonic crystals, while the latter requires low-loss materials (e.g. yttrium iron garnet *or* YIG). However, previous studies on YIG-based magnonic crystals required destructive means [1] of fabricating the devices or required the integration of lossy metallic magnets [2]. An alternative means to produce these devices is to lithographically pattern YIG structures on existing YIG thin films.

Here, we present micromagnetic simulations of magnonic crystals containing only YIG. We show that propagating surface modes (i.e. Damon-Eshbach *or* DE) can be critically suppressed upon incidence with periodic YIG steps in selective bands while maintaining high transmission between these bands. Therefore, these structures produce efficient filtering and propagation in devices that can be fabricated by standard lithographic techniques and room-temperature YIG deposition on existing films [3] without introducing additional damage-induced losses.

References: [1] Serga *et al. J. Phys. D: Appl. Phys.* **43** 264002 (2010). [2] Qin *et al., Nat. Comm.* **9**, 5445 (2018). [3] Hauser *et al. Sci. Rep.* **6**, 20827 (2016).

MA 20.14 Tue 16:30 Poster A

Micromagnetic simulation of nanogratings as possible devices for unidirectional spin wave propagation — •Markus Kügle[1,2], Monika Scheufele[1,2], Matthias Althammer[1,2], Hans Huebl[1,2,3], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Devices enabling unidirectional spin wave (SW) propagation have emerged as promising candidates for the next generation of magnonic logic devices. Here, we investigate a possible realization of such a system in ferromagnetic nanogratings positioned on planar thin films, which act as the SW medium. In this approach, the dipolar coupling induced by the grating is seen as the origin of a finite non-reciprocity in the SW propagation [1]. Using micromagnetic simulations, we first focus on the broadband ferromagnetic resonance response, the SW transport as well as the SW dispersion relation of such ferromagnetic nanogratings. This allows us to determine the mutual coupling regimes of the nanowires when varying wire width and spacing. We then analyze possible unidirectional SW propagation effects in bilayers of ferromagnetic nanogratings on planar ferromagnetic thin films and compare the simulations to experimental results of $Co_{25}Fe_{75}$ nanogratings on yttrium iron garnet thin films.

MA 20.15 Tue 16:30 Poster A

Micromagnetic simulations of spin wave propagation in corrugated waveguides — •Ashfaque Thonikkadavan and Riccardo Hertel — Université de Strasbourg and CNRS, Institut de Physique et Chimie des Matériaux de Strasbourg, F-67000 Strasbourg, France

The spin-wave dynamics in ferromagnets with periodic patterning can display properties of magnonic crystals, like the appearance of magnon band structures with forbidden frequency gaps. A wide variety of magnonic crystals have been investigated over the past years, including arrays of spatially separated nanomagnets and magnetic thin films with periodically modulated material parameters. Progress in three-dimensional magnetic nanofabrication has made it possible to study systems with geometric, rather than structural, modulations. Here, we investigate the magnonic properties of a micron-sized Permalloy thin-film element with a sinusoidally undulated surface using finite-element micromagnetic simulations. In this case, the surface curvature varies periodically, with sub-micron periodicity, while the magnetic material properties and the film thickness (10 nm) are constant throughout the sample. The curvature induces a local shape anisotropy sufficiently strong to align the magnetization perpendicular to the corrugation direction at zero field. We study the spin-wave propagation in Damon-Eshbach geometry and its dependence on the periodicity and amplitude of the modulation. We find that the system shows features of a gapless one-dimensional magnonic crystal. In contrast, a band gap develops when an external field is applied along the corrugation direction, i.e., in the case of backward-volume spin waves.

MA 20.16 Tue 16:30 Poster A

Impact of a lateral gradient in the ferromagnet thickness on the ultrafast response of a spintronic THz emitter — •Paul Alexander Marschall[1], Wolfgang Hoppe[1], Oliver Gückstock[2], Tobias Kampfrath[2], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics, Halle (Saale), Germany — [2]Freie Universität Berlin, Physics, Berlin, Germany

Illuminating a nanometer thin metallic bilayer consisting of a ferromagnetic (FM) and a non-magnetic layer (NM) with an intense femtosecond laser pulse launches an ultrafast spin current from the FM into the NM and is subsequently converted into a charge current in the NM. This system is established as a so called spintronic terahertz emitter usable either as source for THz radiation [1] or for on-chip ultrafast current pulses [2]. By applying an external magnetic field the polarity of radiation or current can be fully inverted. Introducing a lateral gradient in the FM thickness leads to a significant ultrafast response which is not switchable by an external magnetic field and depends on the FM thickness. In this study the origin of this signal is systematically investigated.

[1] T. Seifert et al. Efficient metallic spintronic emitters of ultrabroadband terahertz radiation. Nature Photon 10, 483-488 (2016)

[2] W. Hoppe et al., On-chip generation of ultrafast current pulses by nanolayered spintornic terahertz emitters. ACS Applied Nano Materials 4 (7), 7454-7460 (2021)

MA 20.17 Tue 16:30 Poster A

Magnetization manipulation with Terahertz electric currents — •Holger Grisk[1], Robin Silber[2], Jakob Walowski[1], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald, Germany — [2]IT4Innovations & Nanotechnology Centre, Ostrava, Czech Republic

Operating electronic devices in the Terahertz band remains challenging. Nevertheless, it is important to meet the escalating need for greater computational capacity. Spintronic Terahertz Emitters (STEs) represent a recent breakthrough, allowing for sub-picosecond electric current transients generation using femtosecond laser pulses. STEs, typically a nanometer-thick ferromagnetic/nonmagnetic metal bilayer, might offer integration into electric circuits. For instance, probing the magnetic stack's response to electric current pulses, demonstrated with older LT-GaAs Terahertz Emitters, can now be achieved using STEs as both the source and detector. To facilitate experiments, we develop a shadow mask for optical lithography using direct laser writing. This mask comprises two STEs connected by a gold wire. Diagnostic pump-probe experiments involve pumping the first STE to induce a current transient, while the second Terahertz Emitter's magnetization dynamics are probed using the Time-Resolved Magneto-Optic Kerr Effect (TR MOKE).

MA 20.18 Tue 16:30 Poster A

Magnetization manipulation with Terahertz electric currents — •Holger Grisk[1], Robin Silber[2], Jakob Walowski[1], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald, Germany — [2]IT4Innovations & Nanotechnology Centre, Ostrava, Czech Republic

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MA 20.19 Tue 16:30 Poster A

THz spin and charge currents in a non-centrosymmetric ferromagnet — Junwei Tong[1], Zdenek Kaspar[1], Afnan Alostaz[1,5], Bruno Serrano[1], Xianmin Zhang[2], Genaro Bierhance[1,4], F. Gerhard[3], Johannes Kleinlein[3], Tobias Kiessling[3], Charles Gould[3], Laurens Molenkamp[3], Tom Seifert[1], and •Tobias Kampfrath[1,4] — [1]Freie Universität Berlin, Germany — [2]Northeastern University, China — [3]Physikalisches Institut der Universität Würzburg (EP3), and Institute for Topological Insulators, Am Hubland, Germany — [4]Fritz Haber Institute of the Max Planck Society, Germany — [5]Jülich Research Center, Germany

Investigating spin-to-charge conversion (SCC) on ultrafast time scales is important for understanding its physical mechanisms and the development of terahertz (THz) sources. SCC may arise from, e.g., the inverse spin Hall effect and spin-galvanic effect, whose experimental separation is challenging. Here, we use a femtosecond laser pulse to excite thin films of the ferromagnetic Heusler compound NiMnSb and measure the emitted THz electromagnetic pulse. We observe THz signals and, thus, ultrafast photocurrents that can be ascribed to SCC by contributions with Rashba- and Dresselhaus-like symmetry. Based on a symmetry analysis, we separate both contributions and find that the related photocurrents exhibit different temporal dynamics. Further, by changing the magnetic field, we observe that the Rashba-like current is mainly induced by ordinary Hall effect, whereas the Dresselhaus-like current is independent of the magnetic field strength. We discuss possible microscopic scenarios of the Dresselhaus-like contribution.

MA 20.20 Tue 16:30 Poster A

Magnetic Alloy Spintronic Teraherz Emitters — •David Stein[1], Robert Schneider[2], Mario Fix[1], Jannis Bensmann[2], Steffen Michaelis des Vasconsellos[2], Rudolf Bratschitsch[2], and Manfred Albrecht[1] — [1]Univerity of Augsburg, Germany — [2]University of Münster, Germany

Spintronic THz emitters are a fairly recent development in spintronics and promise advantages compared to existing semiconductor-based emitters. Different bilayer und multilayer thin film systems and alloys are being investigated, in order to determine the influence of different elements on the THz emission and gain understanding of the underlaying processes. One focus of the investigation is the interface between the thin film bilayers and multilayers, which are investigated using atomic resolution STEM and EDS.

MA 20.21 Tue 16:30 Poster A

Narrow band THz Frequency emission from Micropatterned THz emitters — •Nikos Kanistras[1], Quentin Remy[2], Reza Rouzegar[2], Tobias Kampfrath[2], and Georg Schmidt[1] — [1]Institut für Physik, Martin-Luther Universität Halle Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany

THz frequency devices have gained significant attention driven by widespread application potential ranging from communication to non-destructive characterization techniques to astrophysics applications. Spintronic THz Emitters (STEs) show great potential to complement conventional semi-conducting materials due to their straightforward and cost-effective fabrication techniques resulting in seamless on-chip integration with modern device technologies[1].

While typical STEs exhibit a very broad emission spectrum[2], in some cases a narrow emission band may be preferred.

In this work we present a micropatterned spintronic THz emitter based on CoFeB/Pt bilayer, which creates a THz burst corresponding to a narrow band emission at the burst's fundamental frequency. The samples were fabricated by DC sputtering and optical lithography. The THz emission measurements were performed with a wide band detection range up to 40 THz. These devices demonstrate a viable and straightforward method to produce controlled emission in a well-defined THz frequency band.

[1] Seifert et al. Nature Photon 10, 483-488 (2016).
[2] Schmidt et al. Phys. Rev. Appl.,19:L041001 (2023).

MA 20.22 Tue 16:30 Poster A

Theory of spin polarization of transverse electron currents in ferromagnets — •Ilja Turek[1], Alberto Marmodoro[2], Sergiy Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics of Materials, Czech Acad. Sci., Brno, Czech Rep. — [2]Institute of Physics, Czech Acad. Sci., Prague, Czech Rep. — [3]Ludwig Maximilians University, Munich, Germany

Motivated by recent theoretical [1] and experimental [2] studies, we discuss selected aspects of the spin Hall effect in ferromagnets. We focus on cases with fixed directions of the applied electric field and of the induced electron current, and investigate the spin polarization of the latter as a function of the direction of magnetization of the ferromagnet. Based on a group-theoretical analysis [3] and on computations for a 2D tight-binding model [1] and for bulk ordered and disordered iron-based systems, we examine the range of validity of a simple formula suggested by Amin et al. [1]. We find that this formula does not contain terms odd with respect to time reversal, which are of various importance in the studied systems.

[1] V. P. Amin et al., Phys. Rev. B 99 (2019) 220405. [2] N. Soya et al., Phys. Rev. Lett. 131 (2023) 076702. [3] M. Seemann et al., Phys. Rev. B 92 (2015) 155138.

MA 20.23 Tue 16:30 Poster A

Soft x-ray detection of spin-orbit torque mediated magnetization switching and exchange bias effect in FeSi thin films — Victor Ukleev[1], Chen Luo[1], James Taylor[1,2], Tomohiro Hori[3,4], Yoshinori Tokura[4,5], Naoya Kanazawa[3], and •Florin Radu[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Institute of Physics, Martin-Luther-University Halle-Wittenberg, Halle, Germany — [3]Institute of Industrial Science, The University of Tokyo, Tokyo, Japan — [4]Department of Applied Physics, University of Tokyo, Tokyo, Japan — [5]RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan

The emergence of non-trivial magnetotransport in materials without inversion symmetry challenges the current understanding of magnetic phenomena and paves new ways of coupling spin and orbital degrees of freedom [1]. Recently a topological surface state emergent at the surface of chiral insulator FeSi has been demonstrated [2]. In contrast to bulk FeSi, this surface state has a metallic conductivity and ferromagnetic order below ~150 K. Here, we demonstrate a novel experimental technique based on polarization-dependent synchrotron soft x-ray spectroscopy that allows simultaneous detection of the anomalous Hall effect and bulk-sensitive fluorescence x-ray magnetic circular dichroism. The method allows us to detect spin-orbit torque switching of the surface state magnetization. Furthermore, we observe zero-field switching due to interface-induced exchange bias phenomena. [1] Soumyanarayanan, A. et al., Nature 539, 509*517 (2016). [2] Ohtsuka, Y., et al., Sci. Adv. 7, eabj0498 (2021).

MA 20.24 Tue 16:30 Poster A

Probing Hybrid Chiral-Molecule/Metal Interfaces Via Spin Hall Magnetoresistance — •Simon Sochiera[1], Ashish Moharana[1], David Anthofer[1], Fabian Kammerbauer[1], Jens-Georg Becker[2], Alex Hagenow[2], Eva Rentschler[2], and Angela Wittmann[1] — [1]Institute for Physics JGU, Mainz, Germany — [2]Chemistry Department JGU, Mainz, Germany

Chiral molecules have gained significant attention in the spintronics community due to their ability to polarize electron spin angular momentum. Several optical and electrical methods confirmed the chiral-induced spin selectivity effect (CISS; Nat. Rev. Chem. 3, 250 (2019)). Spin Hall magnetoresistance is a powerful tool to probe the spin-transport properties of the hybrid chiral molecule metal interface. Using this technique, we probe the impact of the adsorption of chiral molecules on metal thin films on the spin transport properties and the interfacial effective spin-orbit coupling of the hybrid system. Understanding the effect of molecules in spintronic devices will open up new possibilities for the development of novel hybrid chiral-molecule spintronic devices.

MA 20.25 Tue 16:30 Poster A

Epitaxy of Fe/Rh bilayers with efficient spin pumping — •Jonas Wiemeler[1], Ali Can Aktas[1], Ivan Tarasov[1], András Kovács[2], Rafal Dunin-Borkowski[2], Michael Farle[1], and Anna Semisalova[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Ernst Ruska-Centre, Forschungszentrum Jülich, 52428 Jülich, Germany

We investigate the growth and epitaxy of Rh on Fe(001)/GaAs(001)-4x6 ultra thin bilayer deposited using molecular beam epitaxy in ultrahigh vacuum (5E-10 mbar). We use in situ low-energy electron diffraction and Auger electron spectroscopy during growth, as well as cross-sectional transmission electron microscopy, X-ray diffraction and x-ray circular magnetic dichroism, and show that the Fe/Rh interface is atomically sharp and Rh is not magnetically polarised. The fcc-Rh layers grow 45° rotated to the bcc-Fe lattice, that is Rh(001)[110]||Fe(001)[100] to minimise the lattice mismatch to ≈6%. Cross-section TEM reveals high crystallinity with minimal misfit dislocation defects of 0.2 defects/nm at the interface with Fe. Rh grows in a layer-like Stranski-Krastanov mode on the Fe substrate [1]. Using conventional broadband ferromagnetic resonance, we find that the Fe/Rh bilayer system shows a high spin pumping efficiency with the spin-mixing conductance $g_{mix}^{\uparrow\downarrow} = (2.5 \pm 0.2) \cdot 10^{19}\,\mathrm{m}^{-2}$ comparable to that of Fe/Rh bilayers [2,3]. Financially supported by DFG Projects: CRC/TRR 270 No. 10405553726 and No. 39240249 (SE 2853/1-1) [1] T. Kachel et al., PRB 46, 12888 (1992), [2] A. Conca et al., PRB 93, 134405 (2016), [3] T. Papaioannou et al., APL 103, 162401 (2013)

MA 20.26 Tue 16:30 Poster A

Spin transport in Fe_4GeTe_2 van der Waals heterostructures — •Masoumeh Davoudiniya and Biplab Sanyal — Department of Physics and Astronomy, Uppsala University, Box 516, 751 20 Uppsala, Sweden

Through first-principles calculations, this study aims to theoretically investigate the spin-dependent electronic transport properties within Fe_4GeTe_2 (F4GT) -based van der Waals heterostructures, a class of 2D itinerant ferromagnets with a Curie temperature approaching room temperature. We will illustrate spin-polarized ballistic transport in configurations involving single- or bi-layer F4GT interfaced with $PtTe_2$ electrodes. The electronic density of states, whether for free-standing or device-configured F4GT, unequivocally confirms its ferromagnetic metallic character. Notably, it reveals a weak interface interaction between F4GT and $PtTe_2$ electrodes, which preserves the magnetic properties of free standing F4GT. In the scenario of a double-layer F4GT with a ferromagnetic configuration situated between $PtTe_2$ electrodes, an anticipated spin polarization of an impressive 97% is observed. Furthermore, the spin transport characteristics of F4GT/GaTe/F4GT vdW heterostructures, positioned between $PtTe_2$ electrodes, have been studied to assess their potential as magnetic tunnel junctions in spintronic devices. The introduction of GaTe as a 2D semiconducting spacer between F4GT layers yields a tunnel magnetoresistance of 487% at low bias. These findings present novel prospects for formulating and enhancing spintronic devices based on FGT and similar heterostructures.

MA 20.27 Tue 16:30 Poster A

Theory of magnon mediated electric current drag from nonlocal spin-Hall magnetoresistance in the ac regime — •Oliver Franke, Duje Akrap, Ulli Gems, David A. Reiss, and Piet W. Brouwer — Dahlem Center for Complex Quantum Systems and Physics Department, Freie Universitaet Berlin, Arnimallee 14, 14195 Berlin, Germany

The spin-Hall effect (SHE) allows the conversion between an electric and spin current in normal metals with spin-orbit coupling. In bilayer systems consisting of a normal metal (N) and a ferromagnetic insulator (F), this gives rise to a small correction to the electrical resistance of a charge current through N due to a spin-transfer torque acting on the magnetization in F, called spin-Hall magnetoresistance (SMR). It has been proposed and measured that the same effects can cause a nonlocal charge current in N|F|N trilayers, whereby the charge current is transmitted through an electrical insulator by magnons. In this poster, we present a theory for this nonlocal SMR for the first time in the ac regime up to terahertz driving frequencies and derive its local and nonlocal electrical conductivity up to second order in the applied electric field, which includes rectification effects and Joule heating. By employing a diffusive transport theory for thermal magnons and heat, our theory also incorporates the spin Seebeck effect (SSE).

MA 20.28 Tue 16:30 Poster A

Studying Moire magnetism with diamond scanning probe — •King Cho Wong — Physics Institute 3

Moiré superlattices of twisted magnetic two-dimensional (2D) materials are interesting platforms for creating peculiar magnetic states. Here, we report emerging novel magnetic textures in twisted double bilayer chromium triiodide (tDB-CrI3). Using single-spin quantum magnetometry, we directly visualized nanoscale magnetic domains and patterns, and measured domain and domain wall size. In twisted bilayer CrI3, we observed the coexistence of antiferromagnetic (AFM) and ferromagnetic (FM) domains with twisted angle dependence. We also observed peculiar magnetic phase in the samples. Our results highlight magnetic moiré superlattices as a platform for exploring nanomagnetism.

MA 20.29 Tue 16:30 Poster A

Helical magnetic order in a polar Weyl semimetal RAlSi — •Ryota Nakano[1], Rinsuke Yamada[1], Sebastian Esser[1], Masaki Gen[2], Akiko Kikkawa[2], Yasujiro Taguchi[2], Maurice Colling[3], Jan Masell[2,3], Masashi Tokunaga[2,4], Hajime Sagayama[5], Hiroyuki Ohsumi[6], Yoshikazu Tanaka[6], Taka-hisa Arima[2,7], Yoshinori Tokura[1,2,8], and Max Hirschberger[1,2] — [1]Dep. of Applied Physics, University of Tokyo, Japan — [2]RIKEN CEMS, Japan — [3]Inst. of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany — [4]ISSP, University of Tokyo, Japan — [5]Inst. of Materials Structure Science, KEK, Japan — [6]RIKEN SPring-8, Japan — [7]Dep. of Advanced Materials Science, University of Tokyo, Japan — [8]Tokyo College, University of Tokyo, Japan

Recently, materials exhibiting both Weyl points and non-collinear or non-coplanar spin textures have been intensely studied. RAlSi/RAlGe (R = rare earth ion) is a promising platform, having Weyl nodes due to their non-centrosymmetric crystal structure, and showing versatile magnetic structures by substituting rare earth ions. Our recent study reveals large anisotropic magnetoresistance in RAlSi. In this presentation, we report various types of helimagnetic order in RAlSi by resonant X-ray scattering measurements, including polarization analysis of the scattered X-rays, at Photon Factory and SPring-8 in Japan.

MA 20.30 Tue 16:30 Poster A

Stabilization of magnetic hopfions in bulk magnets — •Sandra Chulliparambil Shaju[1], Ross Knapman[1], Maria Azhar[1], Riccardo Hertel[2], and Karin Everschor-Sitte[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Université de Strasbourg, CNRS, Institut de Physique et Chimie des Matériaux de Strasbourg, F-67000 Strasbourg, France

Advanced nanofabrication techniques and novel 3D magnetization visualization methods have inspired significant research in 3D nanomagnetism, uncovering intriguing nanostructures and physics beyond the realms of 1D and 2D. A fascinating discovery arising from this exploration is that of magnetic hopfions, three-dimensional topological magnetic textures [1,2,3]. In references [4,5] the stabilization of magnetic Hopfions through higher-order exchange interactions in bulk magnets has been proposed. We investigate theoretically the influence of the different model parameters on the Hopfion properties for Hopfions stabilized by such higher-order exchange interactions. We further look for novel Hopfion stabilization mechanisms.

References:

[1] P. Sutcliffe, Phys. Rev. Lett. 118 (2017)
[2] Y. Liu, et al., Phys. Rev. B 98 (2018)
[3] F. Zheng, et al., Nature 623 (2023)
[4] F. N. Rybakov, et al., APL Mat. 210 (2022)
[5] M. Sallermann, et al., Phys. Rev. B 107(2023)

MA 20.31 Tue 16:30 Poster A

Conservation laws and dynamics of 3D topological spin textures — •Maximilian Röhrich[1], Sopheak Sorn[1], Stavros Komineas[2], and Markus Garst[1] — [1]Karlsruhe Institute of Technology, Germany — [2]University of Crete, Greece

With the advent of 3D magnetic imaging techniques, spin textures varying in three spatial dimensions are at the focus of research with magnetic hopfions being a prominent example. In this work, we investigate the dynamics of such textures from the perspective of fundamental conservation laws associated with translational and rotational symmetry. We show that these symmetries imply the conservation of linear, p, and angular momentum, l, which can be expressed, respectively, in terms of the first and second moment of the vorticity, i.e., the 3D generalization of the topological density. Using these results, we derive equations of motion for the rigid translational and rotational motion of the texture that are parametrized by the conserved quantities p and l. Our analytical results are confirmed by numerical simulations.

MA 20.32 Tue 16:30 Poster A

Effects of curvature and torsion on domain wall velocity in antiferromagnetic helix-shaped spin chain exposed to rotating magnetic field — •Yelyzaveta A. Borysenko[1], Kostiantyn V. Yershov[2], Denis D. Sheka[3], and Jeroen van den Brink[2] — [1]Department of Physics, University of Konstanz, DE-78457 Konstanz, Germany — [2]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [3]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Antiferromagnetically ordered (AFM) spin chains arranged along space curves possess geometry-driven magnetic interactions, described by chain curvature and torsion. These interactions by symmetry resemble anisotropic and Dzyaloshinskii-Moriya contributions, originate from exchange, dipolar interaction and intrinsic anisotropy in samples of curved shape [1, 2] and determine the ground state and spin dynamics of such systems [2, 3]. Here, we investigate helix-shaped AFM spin chains (constant curvature and torsion) and describe domain wall dynamics in such system being exposed to rotating magnetic field. Domain wall propagates with velocity, proportional to magnetic field frequency. The relation between the external field and geometrical parameters of the spin chain determines two motion modes: oscillating one and rigid motion with a constant velocity. Curvature and torsion strongly affect stability conditions of the rigid motion mode and domain wall velocity. [1] O. V. Pylypovskyi et al., App. Phys. Lett., 118, 182405 (2021); [2] O. V. Pylypovskyi et al., Nano Lett., 20, 8157-8162 (2020); [3] D. Makarov et al., Adv. Mat., 34, 2101758 (2022)

MA 20.33 Tue 16:30 Poster A

Friedel oscillations induced by three-dimensional topological spin-textures — •Moritz Winterott[1,2] and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

Far-reaching progress was made in the field of three-dimensional spin-textures, especially their potential application in upcomming information storage devices is moving efficient identification and interaction between them further into the focus. We examine these exciting questions from a new perspective, inspired by new findings for the two-dimensional skyrmion [1], we find that three-dimensional spin-textures also carry an electric charge that causes Friedel oscillations. These ripples in the charge density trigger exciting questions, for instance all-electrical interaction and identification of these three-dimensional spin-textures. The non-collinearity of a spin-texture induces a redistribution of the charge density with respect to the collinear ferromagnetic background, which we address by employing a tight-binding model, together with multiple scattering theory. We investigate the impact of spin-orbit coupling, exchange splitting, hopping and position of the d-state with respect to the Fermi energy for different three-dimensional spin-textures of different sizes.

– Project funded by DFG (SPP 2137: LO 1659/8-1).

–[1] M. Bouhassoune & S. Lounis, *Nanomaterials* **11**, 194 (2021).

MA 20.34 Tue 16:30 Poster A

Simulation and experimental studies on synthetic antiferromagnets irradiated by focussed He+ ion beam irradiation — •Fabian Samad[1,2], Gregor Hlawacek[2], Toni Hache[2,3], Helmut Schultheiss[2], Attila Kákay[2], and Olav Hellwig[1,2] — [1]University of Technology Chemnitz, Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany

We present simulation and experimental studies on a synthetic antiferromagnet (SAF) with perpendicular magnetic anisotropy (PMA) [1]. The system is locally manipulated with focused He+ ion beam irradiation on the nano- and micro-scale, inducing the creation of field reconfigurable magnetic textures in the SAF [2]. In a second step we investigate a hybrid system consisting of the SAF and an additional soft magnetic layer on top, with the SAF magnetic textures acting on the soft layer via their stray field. The resulting magnetic structures in the soft layer were probed via magnetic force microscopy (MFM). Our studies demonstrate the possibility to create reconfigurable in-plane oriented regions in the soft layer, which may be utilised, for example, for guiding spin waves in the Damon-Eshbach mode [3,4].

References: [1] Hellwig et al., JMMM 319, 13 (2007) [2] Samad et al., APL 119, 022409 (2021) [3] Qin et al., Nano Letters 22, 5294 (2022) [4] Szulc et al., ACS Nano 16, 14168 (2022)

MA 20.35 Tue 16:30 Poster A

Modeling the training effect in exchange-biased bilayers for large numbers of magnetization reversal cycles — Johannes Fiedler[1], Martin Wortmann[2], Tomasz Blachowicz[3], and •Andrea Ehrmann[1] — [1]Bielefeld University of Applied Sciences and Arts, Faculty of Engineering and Mathematics, Bielefeld, Germany — [2]Bielefeld University, Faculty of Physics, Bielefeld, Germany — [3]Silesian University of Technology, Institute of Physics - Center for Science and Education, Gliwice, Poland

The exchange bias (EB) is a unidirectional anisotropy which occurs, e.g., upon field-cooling ferromagnet/antiferromagnet systems. In many material systems, the EB field is reduced from one hysteresis loop to the next measurement. This so-called training effect (TE) has been investigated in experiments and by means of theoretical efforts by many research groups. The reduction of the EB field as a result of subsequent magnetization reversal processes is often fitted by a power law, usually with the exception of n=1, or with an equation based on the discretized Landau-Khalatnikov (LK) equation, as firstly suggested by Binek. Few other models, usually with more fitting parameters, have been proposed yet. Here we show that for large numbers of subsequent magnetization reversal processes in Co/CoO thin film samples, a modified power law or a logarithmic fit can model the training effect significantly better than the above mentioned, commonly used models.

MA 20.36 Tue 16:30 Poster A

Collective out-of-plane magnetization reversal in tilted stripe domain systems via a single point of irreversibility — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Gauravkumar Patel[1], Attila Kákay[1], Nikolai S. Kiselev[4], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE — [4]Forschungszentrum Jülich

Periodic magnetic stripe domain patterns are a prominent feature of perpendicular anisotropy thin film systems. Here, we focus on the behavior of $[\mathrm{Co}(3.0\ \mathrm{nm})/\mathrm{Pt}(0.6\ \mathrm{nm})]_X$ multilayers within the transitional regime from preferred in-plane (IP), $X = 6$, to out-of-plane (OOP), $X = 22$, magnetization orientation, particularly, we examine a sample with $X = 11$ repetitions, which exhibits a remanent state characterized by a significant presence of both OOP and IP magnetization components, here referred to as the "tilted" stripe domain state*. We investigate this specific sample with vibrating sample magnetometry, magnetic force microscopy and micromagnetic simulations, and find an unusual OOP field reversal behavior via a remanent parallel stripe domain state and a single point of irreversibility. Finally, we show that this characteristic reversal behavior is a rather general feature of transitional IP to OOP systems by comparing the Co/Pt multilayers with c-axis single Co thin films and Fe/Gd multilayers.

*[L. Fallarino et al., Phys. Rev. B 99, 024431 (2019)]

MA 20.37 Tue 16:30 Poster A

Integration of magnetic garnet thin films on a piezoelectric substrate — •Christian Holzmann, Stephan Glamsch, David Stein, Matthias Küss, and Manfred Albrecht — Institute of Physics, University of Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

On one hand, rare earth iron garnets are the go-to material to study magnons due to their insulating nature and ultra-low Gilbert damping. On the other hand, surface acoustic waves (SAWs) are broadly used in modern devices, e.g. in RF filters. Therefore, exploiting the coupling of SAWs and magnons in garnets offers the potential to design highly efficient magneto-acoustic devices [1].

However, studies involving garnet thin films are mostly focused on epitaxially grown films, while the implementation on non-matching substrates is challenging [2]. In this regard, we show the growth of about 40 nm thick crystalline yttrium (YIG) as well as gadolinium iron garnet (GdIG) films on the often used piezoelectric substrate $LiNbO_3$. By combining film growth via pulsed laser deposition and a post-deposition annealing step, garnet recrystallization in a polycrystalline phase is achieved. Notably, the YIG film shows an in-plane uniaxial magnetic anisotropy due to a non-isometric strain induced by the substrate, while the GdIG film possesses a magnetic compensation point close to room temperature.

[1] Küß et al., ACS Applied Electronic Materials, 5103 (2023).

[2] Holzmann et al., Encyclopedia of Materials: Electronics, 777 (2023).

MA 20.38 Tue 16:30 Poster A

The importance of adhesion layers for the growth of sputter deposited Co/Pt multilayer systems — •Rico Ehrler[1], Tino Uhlig[1], Felix Engelhardt[1], Fabian Samad[1], Peter Heinig[1,2], and Olav Hellwig[1,2,3] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany — [3]Research Center MAIN, D-09126 Chemnitz, Germany

Historically, many studies explored properties of sputter-deposited Co/Pt multilayer (ML) with diverse seed layers and substrates. To improve adhesion, later studies added a thin adhesion layer between oxide substrates and metal seeds, significantly affecting the ML system's structure and magnetics as well.

In our investigation, we employed x-ray reflectivity (XRR), x-ray diffraction (XRD), and atomic force microscopy (AFM) to examine the role of Ta adhesion layers on the structure of a Co/Pt ML system grown on thermally oxidized Si for various sputter deposition pressures. Additionally, we reevaluated the impact of seed layer thickness when using this adhesion layer. Magnetic properties were characterized using SQUID-VSM hysteresis loops and magnetic force microscopy (MFM) images. We found that pressure-dependent structural changes were less pronounced with the Ta adhesion layer, enhancing saturation magnetization and anisotropy, particularly at higher pressures. In contrast, Pt seed layer thickness variations produced minor changes in the ML system's magnetic behavior, differing from older studies without an adhesion layer.

MA 20.39 Tue 16:30 Poster A

Ultrathin Fe and Fe3O4 all-oxide heterostructures: Insights from XPS and MOKE — •Andreas Fuhrberg, Pia Maria Düring, Seema Seema, and Martina Müller — FB Physik - Universität Konstanz, 78464 Konstanz, Deutschland

The interface between two different oxide materials can exhibit emerging properties which may be used in novel oxide electronic devices. In particular, interfaces of 3d transition metal oxides show interesting properties like e.g. confined conductivity, magnetism or ferroelectricity. This work focuses on the interface of the 3d ferromagnetic metal Fe and its oxide Fe3O4 with SrTiO3 (STO). Ultrathin films of Fe with varying thicknesses are deposited on STO (001) substrates by molecular beam epitaxy (MBE) at different temperatures. Using lab- and synchrotron-based x-ray photoelectron spectroscopy (XPS), the chemical properties of the interface with STO are explored and a strongly T-dependent interfacial redox reaction is found.

In-operando hard x-ray photoelectron spectroscopy on MBE-grown Fe3O4 thin films on STO:Nb reveals voltage-dependent changes of the core levels and non-ohmic resistance characteristics.

The magnetic properties of Fe3O4/STO:Nb films with varying oxide thickness are studied using magneto-optic Kerr microscopy (MOKE). Influences originating from the diamagnetic substrate and a shift of the magnetic axes caused by anti-phase boundaries are observed.

MA 20.40 Tue 16:30 Poster A

Growth of Perpendicular Magnetic Anisotropy in Gallium-substituted Yttrium Iron Garnet Thin Films — •Kilian Lenz[1], Olga Gladii[1], Javier Pablo-Navarro[1], Antje Oelschlägel[1], René Heller[1], Jürgen Lindner[1], Oleksii Surzhenko[2], and Carsten Dubs[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [2]INNOVENT e.V. Technologieentwicklung, Prüssingstrasse 27B, 07745 Jena

The substitution of Fe lattice sites of yttrium iron garnet (YIG) liquid-phase-epitaxy-grown films with non-magnetic Ga ions creates a significant perpendicular magnetic anisotropy (PMA). Magnetometry and broadband ferromagnetic resonance were performed to test the magnetic characteristics of these Ga:YIG thin films. The Ga content was varied between 1.1–1.3 f.u. for various thicknesses from 30 to 230 nm. The Ga reduces the remanent magnetization and together with the tensile strain causes a stronger PMA. This results in a drastically increased negative effective magnetization for Ga:YIG films, favoring an out-of-plane easy axis.

We also demonstrate that, independent of the thickness and of the substrate orientation [(001) vs. (111)], the perpendicular magnetic anisotropy gradually increases with increasing Ga-content, resulting in a 14 times larger perpendicular anisotropy for 1.3 f.u. Ga-content compared to pure YIG. This allows for easy tuning of the PMA by simply varying the Ga concentration. One advantage of YIG almost remains, i.e. the Gilbert-damping increases only slightly with the amount of Ga.

MA 20.41 Tue 16:30 Poster A

The valence of Ce in Ce-substituted permanent magnets — •Janosch Tasto[1], Benedikt Eggert[1], Yuan Hong[2], William Rigaut[2], Stéphane Grenier[2], Thibaut Devillers[2], Nathan Yutronkie[3], Fabrice Wilhelm[3], Andrei Rogalev[3], Heiko Wende[1], Nora Dempsey[2], and Katharina Ollefs[1] — [1]Univ. of Duisburg-Essen — [2]Institute Néel — [3]ESRF

The current development in our society towards more green energy conversion and electric mobility comes hand in hand with a rising demand in permanent magnets including critical rare-earth (RE) elements. The availability of these elements is often restricted by either political boundaries or limited abundance. Therefore, replacing heavy RE elements with more accessible ones while maintaining the magnetic properties of the compound is essential.

Here, we study the role of Ce as a candidate to replace heavy RE elements by investigating its 4f/5d valence state in different Ce-substituted permanent magnet systems. X-ray absorption spectroscopy was performed on Ce-Co, Ce-Co-Zn, and Nd-Ce-La-Fe-B systems with varying composition examining respective K and $L_{2,3}$ edges of their components. We correlate our spectroscopic findings with the composition and the magnetic properties in order to understand the influence of Ce-substitution on the magnetic properties.

We thank the Toyota Motor Corporation, the French National Research Agency (ANR-22-CE91-0008) and the German Research Foundation (CRC/TRR 270 and CRC 1242) for financial support.

MA 20.42 Tue 16:30 Poster A

Imprinting Magnetic Textures By Geometrical Transformation — •Aman Singh[1,2], Balram Singh[1,2], Yana Vaynzof[1,2], and Volker Neu[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, 01069 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

The application of magnetic devices largely depends on magnetization patterns and the type and quality of domain walls so control over them is an important step in developing magnetic material systems/devices. We present a simple technique to create different types of magnetization patterns, e.g. alternate out-of-plane up-down domains and in-plane head-to-head and tail-to-tail configurations, by a self-assembled geometrical transformation. This is achieved with the help of a polymer platform which consists of a hydrogel as a swelling layer and a stiff polyimide layer. Upon swelling and un-swelling, the platform transforms reversibly into a multi-winding tube. Depending upon the anisotropy of the magnetic material, regular domain patterns can be created simply by applying a homogeneous magnetic field to the magnetic thin films in the rolled state and then unrolling it. The regular domain patterns imprinted by geometrical transformation (GTMP) are thoroughly characterized by Kerr and magnetic force microscopy, and the corresponding stray field landscape is compared with calculations. By going through the intermediate rolled sample state, this technique also offers the possibility to investigate magnetization processes in 3 dimensions.

MA 20.43 Tue 16:30 Poster A

Signatures of slow magnetization relaxation in current reversal method anomalous Hall effect measurements — Sebastian Beckert[1], Richard Schlitz[2], •Gregor Skobjin[2], Antonin Badura[3], Miina Leiviskä[4], Dominik Kriegner[1,3], Daniel Scheffler[1], Kamil Olejník[3], Eva Schmoranzerová[5], Lisa Michez[6], Vincent Baltz[4], Andy Thomas[1,7], Helena Reichlová[1,3], and Sebastian T. B. Goennenwein[2] — [1]IFMP, TU Dresden, Germany — [2]Department of Physics, University of Konstanz, Germany — [3]Institute of Physics ASCR, Czech Republic — [4]Université Grenoble Alpes, CNRS, CEA, IRIG-Spintec, France — [5]Faculty of Mathematics and Physics, Charles University, Czech Republic — [6]Aix-Marseille Université, CNRS, CINaM, France — [7]IFW Dresden, Germany

Slow magnetization relaxation processes are an important time-dependent property of magnetic materials. We show that a current-reversal based measurement method commonly used in magneto-transport experiments can be harnessed for the quantitative study of slow relaxation processes in magnetic thin films. More specifically, we exploit the anomalous Hall effect response to electrically screen the magnetization relaxation dynamics in micropatterned magnetic thin films. We apply our technique to different thin film materials with perpendicular magnetic anisotropy, as well as a potential altermagnetic compound. We will critically discuss the experimental results, and compare them to lock-in based transport measurements.

MA 20.44 Tue 16:30 Poster A

Investigating antiferromagnetic textures in external magnetic fields — •Sebastian Schultheis[1], Kai Litzius[2], Alexander E. Kossak[3], Julian Skolaut[1], Olena Gomonay[1], and Angela Wittmann[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Universität Augsburg, Augsburg, Germany — [3]Massachusetts Institute of Technology, Cambridge, United States of America

In recent years, research on antiferromagnets has received significant attention due to their favorable properties, including robustness to magnetic fields and ultrafast spin dynamics. However, the understanding of the mechanisms of formation of antiferromagnetic domain structure is still limited compared to ferromagnets. Here, we investigate the domain structure of canted antiferromagnets - such as hematite ($\alpha-Fe_2O_3$) - in external magnetic field. The well established method of Photoelectron Emission Microscopy (PEEM) does not allow for imaging the magnetic domain structure in sizable magnetic fields. Thus, here we use Scanning Transmission X-ray Microscopy (STXM) with linearly polarized X-rays to record X-ray Linear Magnetic Dichroism (XMLD) images of the antiferromagnetic ordering via total electron yield. [1] The acquired images were evaluated using methods of image processing to extract quantities describing the change in antiferromagnetic domain structure. Detailed analysis of this data will advance our understanding of the underlying mechanisms of domain structure formation in antiferromagnets.

[1] A. Wittmann et al., Phys. Rev. B 106, 224419 (2022)

MA 20.45 Tue 16:30 Poster A

Superparamagnetic tunnel junctions for neuromorphic computing — •Jonas Köhler[1], Leo Schnitzspan[1,2], Fabian Kammerbauer[1], Gerhard Jakob[1,2], and Mathias Kläui[1,2] — [1]Institute for Physics, Johannes Gutenberg University, 55122 Mainz — [2]Max-Planck Graduate Center Mainz, 55122 Mainz

Superparamagnetic tunnel junctions (SMTJs) are considered promising candidates for building blocks in neuromorphic computing. Due to thermal excitations, the ferromagnetic free layer can switch its magnetization orientation at the nanosecond timescale. The stochastic behavior of the SMTJs allows them to produce true random numbers with encryption-quality randomness [1]. The state probability and the dwell times may be tuned by an external magnetic field or by an applied current via spin transfer torque. When multiple SMTJs are electrically connected, the spin transfer torque leads to an electrical coupling between the MTJs, with the consequence that their stochastic switching becomes correlated [2].

These properties can be used in neural networks, where MTJs can introduce the noise for noise-based learning methods. In comparison to classical approaches, computing implementations using SMTJs can be more energy-efficient.

[1] L. Schnitzspan, et.al., Phys. Rev. Appl. 20, 024002 (2023)
[2] L. Schnitzspan et. al., arXiv:2307.15165 (2023) (in press Appl. Phys. Lett. 123 (2023))

MA 20.46 Tue 16:30 Poster A

Molecular beam epitaxial growth of Bi_2Te_3 thin films — •Aeneas Leingärtner-Goth[1,2], Monika Scheufele[1,2], Matthias Althammer[1,2], Hans Huebl[1,2,3], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Topological insulators such as Bi_2Te_3 are known to exhibit exotic electronic band structures, leading to robust metallic surface states while their bulk spectrum remains gapped [1]. Their intriguing properties make topological insulators candidates for applications in spintronics and quantum computing; their fabrication, however, remains challenging. For example, both anti-site defects and vacancies in Bi_2Te_3 can lead to an enhanced bulk conductivity that overwhelms the contribution of the surface states. Therefore, high-quality Bi_2Te_3 thin films with low bulk defect concentrations are required. Here, we discuss the fabrication of Bi_2Te_3 thin films on (111)-oriented Si substrates by molecular beam epitaxy monitored by reflection high-energy electron diffraction. We characterize the structural and electric properties of these films by high-resolution X-ray diffraction, atomic force microscopy, and electric transport measurements in order to determine the optimal growth conditions for high-quality Bi_2Te_3 thin films.

[1] Y. L. Chen *et al.*, Science **325**, 178-181 (2009)

MA 21: Phd Focus Session: Altermagnets: Foundations and Experimental Evidence

Altermagnetism, a new type of collinear magnetism, is emerging as a platform to explore a wide array of physics and applications, from topology and superconductivity to dissipationless currents, ultrafast dynamics, efficient charge-to-spin conversion, and giant magnetoresistance. Altermagnets are magnetically compensated and collinear, with opposite magnetic moments residing on crystal-sublattices connected by rotation or mirror symmetries, which, notably, makes their spin symmetries mutually exclusive from collinear ferromagnets and antiferromagnets. Remarkably, as a consequence, particles such as electrons moving inside altermagnets can be strongly spin-polarized and spin-split, even though the magnetism overall compensates. The unconventional splitting sets altermagnets apart as intriguing spin-active material alternatives to conventional ferromagnets and materials with large spin-orbit coupling. In this session, we explore altermagnetism and its potential properties in various areas of solid-state physics by fostering discussion between communities and between young and experienced scientists. Starting from a pedagogical introduction to the field, we will uncover spectroscopic evidence of the spin-polarized electrons, magnetotransport, emerging phenomena in superconductor hybrid systems, and octupolar order, positioning altermagnetism as a new paradigm for addressing diverse applied and fundamental challenges in solid-state research.

Organizers: Anna Birk Hellenes (Johannes Gutenberg University Mainz), Alfred Dal Din (University of Nottingham), Marius Weber (Technical University Kaiserslautern-Landau), Bjørnulf Brekke (Norwegian University of Science and Technology), Miina Leiviskä (Czech Academy of Sciences)

Time: Wednesday 9:30–13:15 Location: H 1058

Invited Talk MA 21.1 Wed 9:30 H 1058

Altermagnets: An unconventional magnetic class — •Tomas Jungwirth — Institute of Physics, Czech Academy of Sciences, Cukrovarnicka 10, 162 00 Praha 6, Czech Republic

Conventional magnets can be divided in two basic classes - ferromagnets and antiferromagnets. In the first part of the talk, we will recall that the ferromagnetic order offers a range of phenomena for energy efficient IT, while the vanishing net magnetization in antiferromagnets opens a possibility of combining ultra-high energy efficiency, capacity and speed of future IT. In the main part of the talk we will move on to our recent predictions of instances of strong time-reversal symmetry breaking and spin splitting in electronic bands, typical of ferromagnetism, in crystals with antiparallel compensated magnetic order, typical of antiferromagnetism. We resolved this apparent fundamental conflict in magnetism by symmetry considerations that allowed us to classify and describe a third basic magnetic class. Its alternating spin polarizations in both crystal-structure real space and electronic-structure momentum space suggested a term altermagnetism. A d-wave spin polarization order in altermagnets is a direct counterpart of the unconventional d-wave superconducting order in cuprates. We will discuss predictions and initial experimental verifications in which altermagnets combine merits of ferromagnets and antiferromagnets, that were regarded as principally incompatible, and have merits unparalleled in either of the two conventional magnetic classes.

Invited Talk MA 21.2 Wed 10:00 H 1058

Experimental evidence of time-reversal symmetry breaking in altermagnetic RuO_2 — •O. Fedchenko[1], J. Minar[2], A. Akashdeep[1], S.W. D'Souza[2], D. Vasilyev[1], O. Tkach[1], L. Odenbreit[1], Y. Lytvynenko[1], Q. Nguyen[3], D. Kutnyakhov[4], N. Wind[4], L. Wenthaus[4], M. Scholz[4], K. Rossnagel[5,4], M. Hoesch[4], M. Aeschlimann[6], B. Stadtmüller[1], M. Kläui[1], G. Schönhense[1], T. Jungwirth[7,8], A. Birk Hellenes[1], G. Jakob[1], L. Šmejkal[1,7], J. Sinova[1,7], and H.-J. Elmers[1] — [1]JGU Mainz, Germany — [2]NTC UWB, Czech Republic — [3]SLAC, USA — [4]DESY Hamburg, Germany — [5]CAU Kiel, Germany — [6]RPTU, Kaiserslautern, Germany — [7]Institute of Physics ASCR, Czech Republic — [8]University of Nottingham, UK

Our experimental study focuses on epitaxial RuO_2, the material of the altermagnetic (AM) class. This class has been predicted to combine properties of ferromagnets (FMs) and antiferromagnets (AFMs). Thus, like AFMs, AMs exhibit compensated magnetic order, and moreover, like FMs, they promote strong spin polarization in the band structure [1]. The corresponding unconventional mechanism is the time-reversal symmetry breaking without magnetization – the primary signature of AMs. Using time-of-flight momentum microscopy, we have spectroscopically measured the key signature of the AM phase, i.e. a magnetic circular dichroism (MCD), for the collinear compensated altermagnet RuO_2 [2].

[1] L. Šmejkal *et al.*, Phys. Rev. X **12**, 011028 (2022).
[2] O. Fedchenko *et al.*, arXiv 2306.02170v1 (2023).

MA 21.3 Wed 10:30 H 1058

Magneto-transport and magnetometry measurements in altermagnetic RuO_2 — •Ruben Dario Gonzalez Betancourt[1,4], Teresa Tschirner[1,2], Philipp Kessler[2,3], Tommy Kotte[5], Dominik Kriegner[4,6], Bernd Büchner[1,2,6], Joseph Dufouleur[1], Libor Šmejkal[4,7], Jairo Sinova[4,7], Ralph Claessen[2,3], Tomas Jungwirth[4,8], Simon Moser[2,3], Helena Reichlová[4,6], and Louis Veyrat[1,2,3] — [1]IFW Dresden — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Germany — [3]Physikalisches Institut, Universität Würzburg, Germany — [4]Institute of Physics, AV ČR, Prague — [5]HLD-EMFL, Helmholtz-Zentrum Dresden-Rossendorf — [6]IFMP, TU Dresden — [7]JGU, Mainz — [8]University of Nottingham

Altermagnets are a newly identified class of magnetic materials [1] that exhibit alternating spin polarization in both their real and reciprocal space. This intriguing feature allows altermagnetic materials to demonstrate important spintronic effects, such as the anomalous Hall effect (AHE), previously believed to be absent in collinear compensated systems. RuO_2 has emerged as an altermagnetic model material, and in this presentation, I will summarize the experimental evidence of the AHE in this material [2,3]. Additionally, I will focus on detailed magnetometry measurements on RuO_2 thin films grown on TiO_2 substrates with various orientations and compare the results with transport measurements.

[1] L. Šmejkal et al., Phys. Rev. X. 12.031042 (2022) [2] Feng, Z., et al. Nat. Electron. 5, 735*743 (2022) [3] T. Tschirner et al., APL Mater. 11, 101103 (2023)

MA 21.4 Wed 10:45 H 1058

Imaging the altermagnetic domain structure in MnTe — •Oliver Amin[1], Alfred Dal Din[1], Evangelos Golias[2], Yuran Niu[2], Alexei Zakharov[2], Sarnjeet Dhesi[3], Tomas Jungwirth[4], Kevin Edmonds[1], and Peter Wadley[1] — [1]University of Nottingham, Nottingham, UK — [2]MAX IV, Lund, Sweden — [3]Diamond Light Source, Harwell, UK — [4]Institute of Physics, Prague, Czech Republic

Altermagnets are collinear, fully compensated magnetic systems, in which the sublattice magnetisations are connected through a rotation symmetry combined with time inversion. This reduced symmetry arises from the asymmetric local environments surrounding the magnetic sites and, as a result, the electronic band structure exhibits large momentum-dependent spin splitting that allows for time-inversion broken phenomena, unique in a compensated magnetic material. Understanding the domain structure of altermagnetic materials is crucial for elucidating the connection between the orientation of the compensated moment, called the Néel vector, and the emergence of time symmetry breaking phenomena. Here we show, in thin film altermagnetic candidate material, α-MnTe, that X-ray magnetic circular dichroism in combination with photoemission electron microscopy (XMCD-PEEM) can be used to spatially resolve domain structure related to the altermagnetic symmetries. We confirm that the orientation of the Néel domains is essential in determining the sign of the XMCD signal and uniquely defines a map of the local sublattice magnetisation direction.

MA 21.5 Wed 11:00 H 1058

Supercell Altermagnets — •Rodrigo Jaeschke-Ubiergo[1], Venkata Krishna Bharadwaj[1], Tomáš Jungwirth[2], Libor Šmejkal[1], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Inst. of Physics Academy of Sciences of the Czech Republic, Praha, Czech Republic

Altermagnets are compensated magnets with unconventional d, g, and i-wave spin order in reciprocal space. So far the search for new altermagnetic candidates has been focused on materials in which the magnetic unit cell is identical to the non-magnetic one, i.e. magnetic structures with zero propagation vector. Here, we substantially broaden the family of altermagnetic candidates by predicting supercell altermagnets. Their magnetic unit cell is constructed by enlarging the nonmagnetic primitive unit cell, resulting in a non-zero propagation vector for the magnetic structure. This connection of the magnetic configuration to the ordering of sublattices gives an extra degree of freedom to supercell altermagnets, which can allow for the control over the order parameter spatial orientation. We identify realistic candidates $MnSe_2$ with a d-wave order, and $RbCoBr_3$, $CsCoCr_3$, and $BaMnO_3$ with g-wave order. We demonstrate the reorientation of the order parameter in $MnSe_2$, which has two different magnetic configurations, whose energy difference is only 5 meV, opening the possibility of controlling the orientation of the altermagnetic order parameter by external perturbations.

MA 21.6 Wed 11:15 H 1058

Spontaneous formation of altermagnetism from orbital ordering — •Johannes Knolle[1], Valentin Leeb[1], Alexander Mook[2], and Libor Smejkal[2] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, TQM, 85748 Garching, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany

Altermagnetism has emerged as a third type of collinear magnetism. In contrast to standard antiferromagnets, sublattices of anti-aligned spins are not connected by simple translations or inversion but require additional real-space rotations. Therefore, most proposals for materials realization concentrate on crystals that already have this low symmetry. Here, we show that altermagnetism can also form spontaneously as an interaction-induced electronic instability in a high symmetry crystal. We provide a microscopic example of a two orbital model showing that the coexistence of antiferromagnetic and orbital order realizes an altermagnetic phase. We quantify experimental observables like the spin conductivity and discuss possible material candidates with orbital ordering.

15 min. break

Invited Talk MA 21.7 Wed 11:45 H 1058

Is my altermagnet ferromagneto-octupolar or ferromagneto-triakontadipolar (and does it matter)? — •Nicola Spaldin — Materials Theory, ETH Zurich, Switzerland

The non-relativistic spin splitting characteristic of altermagnets is usually understood in terms of local antiferromagnetically ordered spin magnetic dipole moments and their associated symmetries. Sometimes it can be helpful, however, to work with a *ferroic* ordering of local entities, all of which have the same size and orientation, rather than an antiferroic arrangement. In particular, ferroic orders often carry a readily identifiable associated macroscopic thermodynamic measurable quantity, such as the magnetization in ferromagnets or the polarization in ferroelectrics. In this talk I will show that d-wave altermagnetism results from the ferroic ordering of local non-relativistic magnetic octupoles. Using MnF_2 as an example, we'll see that this *ferromagneto-octupolarization* provides a convenient framework for understanding or predicting properties such as time-reversal symmetry breaking, piezomagnetism, neutron-scattering asymmetry, surface magnetization and second-order magnetoelectric response, as well as the usual non-relativistic spin splitting. In g-wave altermagnets, the corresponding ferroically ordered quantity is the magnetic triakontadipole, which gives us yet more interesting physics as well as a spectacularly good name.

Invited Talk MA 21.8 Wed 12:15 H 1058

Negative critical current in an altermagnet Josephson junction — •Carlo Beenakker — Instituut-Lorentz, Leiden University, The Netherlands

Altermagnets (metals with a d-wave magnetization that alternates direction in momentum space) differ from ferromagnets and antiferromagnets in that they combine a spin-polarized Fermi surface with a vanishing net magnetization. This unusual combination radically modifies the flow of a supercurrent in a junction where an altermagnet connects two superconductors (Josephson junction). The sign of the supercurrent oscillates as a function of the length of the junction, because of a spin-polarisation of the bound states in the junction (Andreev levels): Spin-up and spin-down levels are phase-shifted in opposite directions.

MA 21.9 Wed 12:45 H 1058

Superconductor-altermagnet memory functionality without stray fields — •Hans Gløckner Giil and Jacob Linder — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

A novel class of antiferromagnets, dubbed altermagnets, exhibit a non-relativistically spin-split band structure reminiscent of *d*-wave superconductors, despite the absence of net magnetization. This unique characteristic enables utilization in cryogenic stray-field-free memory devices, offering the possibility of achieving high storage densities. We here determine how a proximate altermagnet influences the critical temperature T_c of a conventional *s*-wave singlet superconductor. Considering both a bilayer and trilayer, we show that such hybrid structures may serve as stray-field free memory devices where the critical temperature is controlled by rotating the Néel vector of one altermagnet, providing infinite magnetoresistance. Furthermore, our study reveals that altermagnetism can coexist with superconductivity up to a critical strength of the altermagnetic order as well as robustness of the altermagnetic influence on the conduction electrons against non-magnetic impurities, ensuring the persistence of the proximity effect under realistic experimental conditions.

MA 21.10 Wed 13:00 H 1058

Dynamic paramagnon-polarons in altermagnets — •Charles Steward[1], Rafael Fernandes[2], and Joerg Schmalian[1] — [1]Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]University of Minnesota, Minneapolis, USA

The combined rotational and time-reversal symmetry breakings that define an altermagnet lead to an unusual d-wave (or g-wave) magnetization order parameter, which in turn can be modeled in terms of multipolar magnetic moments. Here, we show that such an altermagnetic order parameter couples to the dynamics of the lattice even in the absence of an external magnetic field. This coupling is analogous to the nondissipative Hall viscosity and describes the stress generated by a time-varying strain under broken time-reversal symmetry. We demonstrate that this effect generates a hybridized paramagnon-polaron mode, which allows one to assess altermagnetic excitations directly from the phonon spectrum. Using a scaling analysis, we also demonstrate that the dynamic strain coupling strongly affects the altermagnetic phase boundary, but in different ways in the thermal and quantum regimes. In the ground state for both 2D and 3D systems, we find that a hardening of the altermagnon mode leads to an extended altermagnetic ordered regime, whereas for nonzero temperatures in 2D, the softening of the phonon modes leads to increased fluctuations that lower the altermagnetic transition temperature. In 3D even at finite temperatures, the dominant effect is the suppression of quantum fluctuations

MA 22: Thin Films: Coupling Effects and Exchange Bias

Time: Wednesday 9:30–12:15 Location: H 2013

Invited Talk MA 22.1 Wed 9:30 H 2013

Emergence of intrinsic antiferromagnetic topological solitons in thin films — •Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

Antiferromagnetic (AFM) skyrmions are envisioned as ideal localized topological magnetic bits in future information technologies. In contrast to ferromagnetic skyrmions, they are expected to be immune to the skyrmion Hall effect, might offer terahertz dynamics while being insensitive to magnetic fields and dipolar interactions. Although observed in synthetic AFM structures and as complex textures in intrinsic AFM bulk materials, their realization in non-synthetic AFM films, of crucial importance in racetrack concepts, has been elusive. I will discuss progress in finding combination of materials that can host intrinsic (non-synthetic) topological AFM solitons, which can have intriguing properties. They emerge as single and strikingly interpenetrating chains with non-trivial dynamics in a row-wise AFM Cr film deposited on PdFe bilayer/Ir(111) [1], detectable by all-electrical means [2]. Substituting Cr with Mn yields to frustrated AFM multimerons [3], which are also found in 2D van der Waals heterostructures [4]. These findings open up exciting avenues for engineering and detecting intrinsic AFM chiral entities in the same films. – Project funded by DFG (SPP 2137: LO 1659/8-1; SPP 2244: LO 1659/7-1).
–[1] Nat. Comm. 13, 7369 '22; [2] Nat. Comm. 13, 1576 '22; [3] J. Phys. Chem. Lett. 14, 8970 '23; [4] PRB 108, 094409 '23.

MA 22.2 Wed 10:00 H 2013

Magneto-Optic Kerr Effect in EuO and EuO/Co: Correlating Experiment and Simulations — •Seema Seema, Moumita Kundu, Henrik Jentgens, Paul Rosenberger, Ulrich Nowak, and Martina Müller — Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

Ferromagnetic (FM) and insulating europium oxide (EuO) is perfectly suited as a spin-functional material for spintronic applications. EuO is a strong FM of $7\mu_B$ with a Curie temperature (T_c) of 69 K. The latter limits the practical applications and thus pathways to enhance the Tc have been explored such as altering stoichiometry, doping etc. Alternatively, it is promising to explore EuO in proximity to a room temperature FM such as Fe or Co to realize an enhancement of T_c in EuO ultrathin films. The present work is the temperature-dependent magnetization in EuO probed using magneto-optic Kerr microscopy. Simultaneous hysteresis recording and domain imaging showed proximity effect-induced variations. To picture the magnetization reversal dynamics in EuO and EuO/Co, micromagnetic simulations were performed using OOMMF and MuMax^3 and compared with the experimental findings below and above T_c. Examining the changes induced by the proximity effect on a micromagnetic scale, through both experimental studies and modeling, has the potential to advance the enhancement of the T_c of EuO.

MA 22.3 Wed 10:15 H 2013

Skyrmions stabilization in exchange-biased model systems with compensated, uncompensated, and rough interface — •Maryna Pankratova[1], Olle Eriksson[1,2], and Anders Bergman[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Wallenberg Initiative Materials Science for Sustainability, Uppsala University, 75121 Uppsala, Sweden

The exchange bias appears in systems with contacting ferromagnets (FM) and antiferromagnets (AFM). It manifests itself in the shift of the magnetic hysteresis from the symmetric position with regard to the zero external magnetic field. When only one AFM sublattice is presented at the interface, or uncompensated FM-AFM interface, the magnetization of the AFM interface layer is non-zero, therefore, the effective field acts on the FM from the AFM. When both AFM sublattices are presented in the AFM interface layer, i.e. the case of a compensated interface, such an effective field could appear if two sublattices do not completely compensate each other. Recently, it was experimentally shown that this effective field can be used to stabilize skyrmions in zero external magnetic fields.

We perform atomistic spin-dynamics simulations to study skyrmion stabilizations in an exchange-biased FM-AFM bilayer and the impact of the interface roughness on the skyrmions' stabilization. We show that skyrmions and skyrmion lattices can be stabilized in zero external fields. The presence, stability, and chirality of skyrmions can be tuned by the strength of exchange coupling through the interface.

MA 22.4 Wed 10:30 H 2013

Proximity Effect in DyCo3 thin films investigated by Polarized Neutron Reflectometry — •Dieter Lott[1], André Philippi-Kobs[2], Stefan Mattauch[3], and Alexandros Koutsioumpas[3] — [1]Helmholtz Zentrum Hereon, Geesthacht, Germany — [2]DESY, Hamburg, Germany — [3]JCNS, Jülich Forschungszentrum, Jülich, Germany

Alloys of rare-earth elements and 3d transition metals became recently again in the focus of attention due there rich variety of magnetic effects owed to the different anisotropies of both material classes [1-3]. In a thin film system of amorphous DyCo3 alloy, studied by XMCD techniques, a non trivial magnetic ordering was discovered showing a large Atomic Exchange Bias effect owned to the competition between the atomic exchange and the Zeemann interaction [4]. Here in this work, polarized neutron reflectometry was applied providing the sensitivity to study the magnetic structures on a microscopic level that is essential to understand the underlying principles. Here, in particular, the Ta buffer and Ta capping layer has a significant effect on the magnetic properties of DyCo3 leading to a significant proximity effect. The results demonstrate how the choice of the proximity layers may be key to further tailor the magnetic properties of this material system for potential future applications. [1] S. Mangin et.al, Phys. Rev. B 80, 224424 (2009), S. Mangin et.al, Phys. Rev. Lett. 82, 4336 (1999) [2] Chen, K., Lott, D. et al.. Phys. Rev. B 91, 024409 (2015) [3] F. Radu, R. Abrudan, I. Radu, D. Schmitz H. Zabel, Nat. Communications 3, 715 (2012). [4] K. Chen, D. Lott, F. Radu, F. Choueikani, E. Otero, P. Ohresser, Sci. Rep. 5, 18377, (2015)

15 min. break

MA 22.5 Wed 11:00 H 2013

Enhanced magnetism at 3d FM/EuO interfaces: Insights from core level photoelecton spectroscopy — •Paul Rosenberger[1,2], Moumita Kundu[1], Andrei Gloskovskii[3], Christoph Schlüter[3], Ulrich Nowak[1], and Martina Müller[1] — [1]FB Physik, Universität Konstanz, Germany — [2]Fakultät Physik, TU Dortmund, Germany — [3]DESY, Hamburg, Germany

The semiconducting Heisenberg ferromagnet EuO ($\mu = 7\,\mu_B$/f.u.) is a template for studying novel spin-related phenomena, but suffers from a rather low T_C (69 K) [1]. A magnetic proximity effect (MPE) in EuO interfaced with Fe or Co results in a T_C enhancement, but its microscopic origin and depth-dependence are not yet understood.
Here, the depth-dependent magnetic order at Fe/EuO and Co/EuO interfaces was studied by emission-angle dependent magnetic circular dichroism (MCD) in hard-X-ray photoelectron spectroscopy (HAXPES). Bilayers with EuO film with thicknesses of 4 nm and 11 nm were measured at T= 40 K < T_C and T= 80 K > T_C. The results confirm antiferromagnetic coupling between the 3d FM overlayers and EuO. At T > T_C, magnetic order in thin EuO is observed. The degree of magnetic order was found to decrease with increasing distance from the interface. Initially magnetized in-plane EuO has a non-zero magnetic out-of-plane component at T > T_C. The experiments are complemented by atomistic spin simulations.

[1] P. Rosenberger and M. Müller, PRM 6, 044404 (2022).

MA 22.6 Wed 11:15 H 2013

Magnetometry of Buried Co-based Nanolayers by Hard X-ray Photoelectron Spectroscopy — •Andrei Gloskovskii[1], Christoph Schlueter[1], and Gerhard Fecher[2] — [1]Photon Science / DESY, Hamburg — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

The intensity and shape of photoelectron lines of magnetic materials depend on the relative orientation of the sample magnetization, the X-ray beam polarization and the spectrometer axis, i.e. the electron emission direction. In the hard X-ray regime, the beam polarization can be conveniently modified utilizing the phase shift produced by a diamond phase plate in the vicinity of a Laue or Bragg reflection. A single-stage in-vacuum phase retarder is installed and commissioned in 2020 at the HAXPES beamline P22 at PETRA III (Hamburg) [1].

The electronic and magnetic properties of CoFe, CoFeB and Co-based Heusler nanolayers were studied using the magnetic circular dichroism (MCD). Both the polarization-dependent spectra and the dichroism indicate that the lines of the multiplet extend over the entire spectral range. It is demonstrated that MCD in HAXPES is an effective and powerful technique to perform element and depth specific magnetometry of deeply buried ferromagnetic and antiferromagnetic magnetic materials. [1] C. Schlueter, A. Gloskovskii, K. Ederer et al., AIP conference proceedings 2054(1), 040010 (2019).

MA 22.7 Wed 11:30 H 2013

Spin currents in ferrimagnetic heterostructures — •Felix Fuhrmann[1], Akashdeep Akashdeep[1], Sven Becker[1], Zengyao Ren[1,2], Mathias Weiler[3], Gerhard Jakob[1,2], and Mathias Kläui[1,2,4] — [1]Institute of Physics, University of Mainz, Germany — [2]Graduate School of Excellence "Materials Science in Mainz" (MAINZ), Germany — [3]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische UniversitätKaiserslautern-Landau, 67663 Kaiserslautern, Germany — [4]Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway

In response to the growing demand for energy-efficient information technology, magnons emerge as promising information carriers [1]. To advance magnon-based devices, essential materials requirements must be met. The insulating ferrimagnet Yttrium Iron Garnet (YIG, $Y_3Fe_5O_{12}$) and related garnets, such as Gadolinium Iron Garnet (GIG, $Gd_3Fe_5O_{12}$), stand out with their low damping and resulting large magnon propagation lengths [1]. Employing pulsed laser deposition, we fabricated heterostructures of YIG and GIG, revealing a ferromagnetic coupling between the Fe sublattices of the two layers, leading to complex magnetic response to external magnetic fields and a nontrivial temperature dependence [2]. Exploring spin current generation via the spin Seebeck effect and spin pumping at ferromagnetic resonance, our findings align with our macrospin model [3]. [1] A. Chumak et al., Nat. Phys. 11, 453 (2015). [2] S. Becker et al., Phys. Rev. Appl., 16, 014047 (2021). [3] F. Fuhrmann et al., ArXiv:2303.15085 (2023).

MA 22.8 Wed 11:45 H 2013

Double Exchange Bias and Ultraslow Magnetization Relaxation in TbFe-based Bilayers — •Johannes Seyd and Manfred Albrecht — Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg

Exchange bias (EB) is a phenomenon that manifests itself in the horizontal shift of a hysteresis loop. This usually occurs in systems with coupled FM-AFM or FM-FiM interfaces. We report on the magnetic reversal characteristics of exchange-biased heterostructures consisting of two ferrimagnetic Tb_xFe_{100-x} layers whose respective magnetizations are Fe-dominated and Tb-dominated. Both layers are amorphous and display perpendicular magnetic anisotropy.

Based on previously published results, we expanded the range of investigated layer compositions of Tb_xFe_{100-x}-based bilayers and layer structures. Since not a sharp interface, but a gradual change of composition over a region of about 2.5 nm thickness between the two layers was found in the bilayer structure, we investigated the influence of different additional interlayers on the magnetic reversal behaviour at low temperatures after field cooling (FC).

While investigating these samples, another phenomenon was observed: ultraslow magnetization relaxation. This manifests itself in an overcrossing of the hysteresis branches in the first and third quarter of the M-H-diagram. Usually, the slowest process in magnetization dynamics is domain wall motion with a timescale between a few ns to hundreds of μs. The process observed here, however, takes in the order of a few tens to thousands of seconds to complete.

MA 22.9 Wed 12:00 H 2013

Investigation of proximity effects in $YBa_2Cu_3O_{7-x}$/$SrRuO_3$ and $SrRuO_3$/$YBa_2Cu_3O_{7-x}$ heterostructures — •Vitor de Oliveira Lima[1,2], Michael Faley[1], Omar Concepcion[1], Connie Bednarski-Meinke[1], Mai H. Hamed[1], Emmanuel Kentzinger[1], Shibrabata Nandi[1,2], and Thomas Brückel[1,2] — [1]Forschungszentrum Jülich GmbH, Jülich, Germany — [2]RWTH Aachen, Lehrstuhl für Experimentalphysik IVc, Jülich-Aachen Research Alliance (JARA-FIT), Aachen, Germany

Heterostructures (HS) based on superconductors and ferromagnets exhibit strong potential for innovating devices in spintronics and quantum computing applications. $SrRuO_3$ (SRO) has attracted much attention among transition metal oxides for being the only 4*d* oxide to show itinerant ferromagnetism and metallic conductivity. On the other side, $YBa_2Cu_3O_{7-x}$ (YBCO) is one of the most studied high T_c superconductors with a large variety of applications. We report structural, morphological, magnetic and magnetotransport characterization of YBCO/SRO (S1) and SRO/YBCO (S2) HS prepared on low miscut $SrTiO_3$ (001) single crystals by high oxygen pressure sputtering. The HS exhibit epitaxial growth with good crystal quality and sharp interfaces, with critical temperatures of 87.5 K and 57 K for S1 and S2, respectively, both reduced in relation to YBCO (91 K). We observe an inversion of the magnetoresistance peak around the onset of superconductivity, a robust indicator of proximity effects at both interfaces. The nature of the proximity effect will be discussed.

MA 23: Magnonics II

Time: Wednesday 9:30–11:00 Location: EB 107

MA 23.1 Wed 9:30 EB 107

Dipolar interactions and critical dynamics in Ni — •Lukas Beddrich[1], Johanna K. Jochum[1], Steffen Säubert[2,3], Christian Franz[4], and Peter Böni[5] — [1]Research Neutron Source Heinz Maier-Leibnitz (FRM II), Technical Universtity of Munich, Garching, Germany — [2]Physik-Department E51, Technische Universität München, Garching, Germany — [3]Department of Physics, Colorado State University, Fort Collins, USA — [4]Jülich Centre for Neutron Science JCNS-MLZ, Forschungszentrum Jülich GmbH Outstation at MLZ FRM II, Garching, Germany — [5]Physik-Department E21, Technische Universität München, Garching, Germany

The spin wave dispersion of an isotropic ferromagnet is described by the Holstein-Primakoff theory, which takes dipolar interactions into account. At low q, the dispersion shows linear behavior instead of $E_{\mathrm{SW}} \propto q^2$, which would be expected. This is attributed to the long-range dipolar interaction between the magnetic moments. The subtle influence of these interactions on the magnon spectrum can be expressed by the dipolar wave vector q_{D}.

Utilizing the modern MIEZE method, a neutron resonance spin-echo technique, we investigated the critical spin dynamics in nickel above and below T_{C}. The measruements were performed at small momentum and energy transfer, reaching an energy resolution that has not been achieved before.

Our results show excellent agreement with spin wave and dynamical scaling theory. However, due to the improved resolution, the measurements strongly suggest q_{D} to be smaller than previously reported.

MA 23.2 Wed 9:45 EB 107

Analysis of magnetoacoustic waves in epitaxial Fe_3Si/GaAs hybrid structures — Marc Rovirola[1], Muhammad Waqas Khaliq[1,2], Blai Casals[1], Michael Foerster[2], Miguel Angel Niño[2], Lucía Aballe[2], Jens Herfort[3], Joan Manel Hernàndez[1], Ferran Macià[1], and •Alberto Hernández-Mínguez[3] — [1]University of Barcelona, Barcelona, Spain — [2]ALBA Synchrotron Light Source, Cerdanyola del Vallès, Spain — [3]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

The magnetoelastic interaction provides an efficient dynamical coupling between surface acoustic waves (SAWs) and spin waves (magnons) in micro- and nanometric magnetic systems. In this contribution, we quantify via magnetic imaging in an x-ray photoelectron microscope the amplitude of magnetoacoustic waves (coupled SAW and spin waves) in a hybrid structure consisting of a 74-nm-thick ferromagnetic Fe_3Si film grown epitaxially on a piezoelectric substrate, GaAs. The cubic anisotropy of Fe_3Si, together with a low damping coefficient, allows for the observation of magnetoacoustic waves with 500 MHz frequency in both resonant and nonresonant conditions, reaching up to 1.5° precession amplitude of the magnetization vector around its equilibrium direction. Finally, we compare the experimental behavior with micromagnetic simulations to quantify the magnetoelastic shear strain constant in Fe_3Si, obtaining $b_2 = 10 \pm 4$ MJ/m^3.

[1] M. Rovirola *et al.*, Phys. Rev. Appl. **20**, 034052 (2023)

MA 23.3 Wed 10:00 EB 107

Higher harmonics generation from low intensity spin waves using a magnon concentrator — •Stephanie Lake[1], Seth Kurfman[1], Rouven Dreyer[1], Georg Woltersdorf[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

Nonlinear magnon interactions, such as magnon-magnon scattering, are well-documented processes in yttrium iron garnet (YIG) films and microstructures[1,2]. In many of these studies, high frequency signals induce ferromagnetic resonance, causing nonlinear processes to occur. However, this method of excitation lacks spatial resolution and typically requires high initial magnon intensities due to propagation losses.

In this work, we demonstrate nonlinear higher harmonic generation from low-intensity spin waves (SWs). First we fabricate a funnel-shaped YIG device, i.e. magnon concentrator, which employs demagnetizing fields to collect and steer SWs. Then with magneto-optical Kerr effect (MOKE) microscopy and micromagnetic simulations, we investigate the propagation of low-intensity SWs through the concentrator, where they ultimately cross the nonlinearity threshold at the focus. These results can facilitate magnonic applications where both precision and nonlinearities are required.

[1] Ordóñez-Romero, César L., et al. *Physical Review B* 79.14 (2009).

[2] Liu, HJ Jason, et al. *Physical Review B* 99.2 (2019).

MA 23.4 Wed 10:15 EB 107

Fabrication and Characterization of Suspended YIG Microstructures — •Seth W. Kurfman[1], Frank Heyroth[2], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin Luther Universität Halle-Wittenberg, Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Efficient coupling between magnetic excitations and acoustic modes is hindered by enhanced phonon loss into the substrate bulk. These losses can be minimized through the fabrication of suspended magnonic microstructures where the acoustic modes of the magnonic material are isolated from the substrate.

Here, we demonstrate the fabrication of low-loss suspended YIG microstructures with a single attached support point. We additionally show characterization of excited magnon modes via optical techniques (*e.g.* TR-MOKE) and inductive measurements. Due to confinement effects, these structures exhibit acoustic resonant modes in the GHz regime and therefore provide an avenue towards efficient coupling of magnetic and acoustic modes. In conjunction with optical techniques (*e.g.* Brillouin Light Scattering) to measure the acoustic modes, these YIG microstructures promise application potential ranging from efficient microwave-to-optical light frequency conversion [1] to quantum systems utilizing coherent multipartite coupling [2].

References:

[1] Engelhardt *et al., Phys. Rev. Appl.* **18**, 044059 (2022).

[2] Lachance-Quirion *et al., Appl. Phys. Express* **12**, 070101 (2019).

MA 23.5 Wed 10:30 EB 107

Nonlinear spin waves in a half-metallic Co_2MnSi waveguide with ultralow magnetic damping — •Anna Maria Friedel[1,2], José Solano[3], Yves Henry[3], Sébastien Petit-Watelot[1], Matthieu Bailleul[3], Philipp Pirro[2], and Stéphane Andrieu[1] — [1]Institut Jean Lamour, UMR 7198 CNRS–Université de Lorraine, Nancy, France — [2]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany — [3]Institut de Physique et Chimie des Matériaux de Strasbourg, UMR 7504 CNRS–Université de Strasbourg, Strasbourg, France

We observe nonlinear spin wave excitation processes at particularly low excitation power thresholds in an epitaxial, half-metallic Co_2MnSi waveguide. Co_2MnSi proofs to be of high interest for magnonics due to the combination of high saturation magnetisation around 1000 kA/m and ultralow Gilbert damping parameters in the 10^{-4} range [1]. The ultralow damping is linked to the compound's 100% spin polarisation, which was confirmed in the investigated waveguide by spin wave Doppler shift measurements. Performing time-resolved Brillouin light scattering microscopy, we study the excitation, propagation and decay of linear and nonlinear spin wave modes. We find a reduced threshold for the observation of 2$^{\mathrm{nd}}$ order instabilities compared to previous studies on sputtered Heusler compounds [2], which we link to the comparably low Gilbert damping parameter in our epitaxial Co_2MnSi waveguide. This research was funded by ANR Contracts No. ANR-20-CE24-0012 (MARIN) and ANR-20-CE24-0023 (CONTRABASS).

[1] Phys. Rev. Appl. **11**, 064009 (2019) [2] PRL **113**, 227601 (2014)

MA 23.6 Wed 10:45 EB 107

Direct measurement of emergent coherence in magnonic condensates — •Malte Koster[1], Matthias R. Schweizer[1], Vitaliy Vasyuchka[1], Dmytro Bozhko[2], Burkard Hillebrands[1], Mathias Weiler[1], Alexander A. Serga[1], and Georg von Freymann[1,3] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Department of Physics and Energy Science, University of Colorado Colorado Springs, CO 80918 USA — [3]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

The formation of magnon Bose-Einstein condensates (BECs) in parametrically overpopulated magnon gas is a subject of long-standing interest to the scientific community. Recently, the possibility of electromagnetic detection of magnon condensates with a frequency resolution finer than the spectral line width of the magnon BEC has been demonstrated. Here, we present a new measurement technique for performing direct electromagnetic measurements of the magnon phases and correlation characteristics in a parametrically pumped magnon gas. In experiments with parametrically driven perpendicularly magnetized yttrium-iron-garnet films, we observe the spontaneous formation of the homogeneous Kittel mode with a random initial phase. Our measurements provide convincing experimental evidence for the spontaneous emergence of coherence in the condensate phase.

This research was funded by the Deutsche Forschungsgemeinschaft in frame of TRR 173/2*268565370 Spin+X (Project B04).

MA 24: Terahertz Spintronics I

Time: Wednesday 9:30–13:15 Location: EB 202

MA 24.1 Wed 9:30 EB 202

Exact diagonalization study of THz two-dimensional spectroscopy in quantum magnets — •Yoshito Watanabe[1], Simon Trebst[1], and Ciarán Hickey[2] — [1]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — [2]School of Physics, University College Dublin, Belfield, Dublin 4, Ireland

Two-dimensional coherent spectroscopy (2DCS) is a method used to study the nonlinear responses of systems. Recent advancements in THz generation techniques suggest the potential for 2DCS in investigating quantum magnets. This approach is theoretically proposed to discern fractionalized excitations in quantum magnets, a capability distinct from traditional linear-response methods.

Current 2DCS research often focuses on solvable models like the one-dimensional transverse field Ising model (1d-TFIM). However, there is a growing need for numerical methods that simulate 2DCS more broadly to interpret experimental data accurately.

This study addresses these methods, specifically using exact diagonalization (ED) to examine one-dimensional models. We outline ways to bridge the gap between numerical simulation results from smaller systems and experimental results typically gathered in the thermodynamic limit.

Having established the numerical techniques, we analyze how integrability-breaking terms affect the 2DCS spectra of the 1d-TFIM, which has experimental relevance to the quasi-1d spin-chain compound CoNb2O6.

MA 24.2 Wed 9:45 EB 202

Accessing ultrafast spin-transport dynamics in copper using broadband terahertz spectroscopy — •Reza Rouzegar[1,3], Jiri Jechumtal[2], Oliver Gueckstock[1,3], Wolfgang Hoppe[5], Quentin Remy[1], Tom Seifert[1], Georg Woltersdorf[5], Piet Brouwer[1], Markus Münzenberg[4], Tobias Kampfrath[1], and Lukas Nadvornik[2] — [1]Freie Universität Berlin — [2]Charles University, Prague — [3]Fritz-Haber-Institute, Berlin — [4]Universität Greifswald — [5]Martin-Luther-Universität Halle

We study femtosecond spin currents through Cu in CoFeB(2 nm)|Cu(d)| Pt(2 nm) stacks by terahertz emission spectroscopy. In our approach, spin currents are transmitted through a Cu(d) interlayer with thickness d and converted into a measurable charge current in Pt. The spin current $j_s^d(t)$ vs time t behind the Cu layer exhibits an increasing delay and stronger dispersion when d increases [1]. Using an analytical dynamic-diffusion model, we can describe the spin current propagation for a spin velocity of 1.1 nm/fs, which agrees well with the Fermi velocity of Cu, and an electron scattering time of $\tau = 4 \pm 2$ fs. In the framework of our model, we can separate ballistic and diffusive components of the spin current [1]. We conclude that, for thicknesses of $d \geq 2$ nm, the spin current is dominated by diffusive transport.

[1] J. Jechumtal, R. Rouzegar, et.al., arXiv:2310.12082 (2023).

MA 24.3 Wed 10:00 EB 202

Observing terahertz orbital-angular-momentum currents with giant relaxation length in tungsten — •Tom Sebastian Seifert — Department of Physics, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Terahertz emission spectroscopy (TES) is a powerful tool to reveal photocurrent dynamics with femtosecond time resolution [1]. An exciting application for TES arises in the emerging field of orbitronics that exploits the electron orbital momentum L for possible data-processing applications [2]. However, direct experimental observation of L currents, their extended propagation lengths and their conversion into charge currents has remained challenging. Here, we optically trigger ultrafast angular-momentum transport in Ni|W|SiO2 thin-film stacks [3]. The resulting terahertz charge-current bursts exhibit a marked delay and width that grow linearly with the W thickness. We consistently ascribe these observations to a ballistic-like L current from Ni through W with a giant decay length (80 nm) and low velocity (0.1 nm/fs). At the W/SiO2 interface, the L flow is efficiently converted into a charge current by the inverse orbital Rashba-Edelstein effect, consistent with ab initio calculations. Our findings establish orbitronic materials with long-distance L transport as possible candidates for future efficient and ultrabroadband orbitronic terahertz emitters, and an approach to discriminate Hall-like and Rashba-Edelstein-like conversion processes.

[1] Leitenstorfer, A., et al., J. Phys. D 56(2023).
[2] Go, D., et al., EPL 135 (2021).
[3] Seifert, T.S., et al., Nat. Nanotechnol. 18, (2023).

MA 24.4 Wed 10:15 EB 202

THz excitations in Fe2Mo3O8 and how they track a highly unusual magnetization reversal — •Joachim Deisenhofer[1], Somnath Ghara[1], Vladimir Tsurkan[1], Lilian Prodan[1], Maxim Mostovoy[2], Evgenii Barts[2], Kirill Vasin[1,3], Mikhail V. Eremin[3], Istvan Kezsmarki[1], Felix Schilberth[1], Dmytro Kamenskyi[1], and Alexey R. Nurmukhametov[3] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands. — [3]Kazan, Russia.

We investigated the THz excitations in the polar honeycomb antiferromagnet Fe2Mo3O8 in external magnetic fields and their optical toroidal effect, together with the temperature dependencee of the electronic transitions in the mid- and near-infrared frequency range. Using an advanced single-ion approach for the Fe ions, we are able to describe the optical excitation spectrum from the THz to the near-infrared regime and model the toroidal optical effect successfully. Moreover, we show that the lowest-lying optical mode tracks an unusual magnetization reversal in lightly Zn-doped Fe2Mo3O8: The magnetization reversal of the field-induced ferrimagnetic state at the coercive field occurs via the antiferromagnetic state, i.e. a magnetization compensation on the atomic level instead of the usual compensation by macroscopic domains.

MA 24.5 Wed 10:30 EB 202

On-chip sub-THz electrical pulse train generation by sequentially emitting Spintronic Terahertz Emitters — •Bikash Das Mohapatra[1] and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Strasse 4, 06120 Halle, Germany

This study explores the concept of using a sequence of ultrashort electrical pulses[1] generated by spintronic THz emitters (STE) integrated into a waveguide. The fundamental frequency of the resulting burst is determined by the position of the respective emitters and the pulse propagation velocity in the waveguide. The result is an electrical pulse train, currently at sub-THz frequencies but theoretically the frequency range can be extended into the THz regime. The electrical response was measured using a 50 GHz sampling oscilloscope. These pulse trains are subject to tuning based on the STE size, path length between the STEs, and the position of the laser spot. Notably, the central frequency of the power spectrum is determined by the inter-STE distance. Furthermore, various temporal and spatial manipulation techniques enable the digital encoding of these pulse trains. This work is quite promising for the development of components with potential Ultrafast Spintronics device applications.

[1] W. Hoppe et al. "On-Chip Generation of Ultrafast Current Pulses by Nanolayered Spintronic Terahertz Emitters", ACS Applied Nano Materials 2021 4(7), 7454-7460, DOI: 10.1021/acsanm.1c01449

MA 24.6 Wed 10:45 EB 202

Terahertz spin transport and spin charge conversion dynamics in topological-insulator|ferromagnet heterostructures — •Genaro Bierhance[1,2], Chihun In[2], Enzo Rongione[3,4], Reza Rouzegar[2], Oliver Gueckstock[2], Emanuele Longo[5,6], Tom Sebastian Seifert[2], Roberto Mantovan[5], Henri Jaffrès[3], Athanasios Dimoulas[7], and Tobias Kampfrath[1,2] — [1]FHI Berlin, Germany — [2]FU Berlin, Germany — [3]CNRS, Paris, France — [4]ICN2, Barcelona, Spain — [5]CNR-IMM, Italy — [6]ICMAB, Barcelona, Spain — [7]NCSRD, Athens, Greece

Topological insulators are promising materials for terahertz (THz) spintronic devices due to their topologically protected surface states with spin-momentum locking, which unveil channels for spin-charge interconversion (SCI). Here, we study ultrafast spin transport and SCI in F|TI stacks consisting of a ferromagnetic metal layer (F) and a topological-insulator film (TI). An incident femtosecond laser pulse induces a spin voltage and, thus, spin transport from F to TI. Subsequent SCI launches a transverse charge current that emits a broadband THz electromagnetic pulse. A detailed analysis of the obtained THz emission signal dynamics in the TI Bi_2Te_3 reveals two relaxation components with distinct time scales: a quasi-instantaneous and a significantly longer response. Remarkably, the extracted time constant (300 fs) of the latter is independent of the chosen F material (Fe or Co). We ascribe these observations to a slower response of either spin transport or SCI in Bi_2Te_3, indicating the importance of intermediate states in these structures.

MA 24.7 Wed 11:00 EB 202

Tunable ultrabroadband hybrid terahertz emitter combining a spintronic terahertz source and a GaSe crystal — •Afnan Alostaz[1,2], Oliver Gueckstock[1], Jungwei Tong[1], Jana Kredl[3], Chihun In[1], Markus Münzenberg[3], and Tom S. Seifert[1] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Peter Grünberg Institut-6, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Institut für Physik, Universität Greifswald, Greifswald, Germany

Linear terahertz time-domain spectroscopy (THz-TDS) is a sensitive probe for material characterization including thickness measurements of thin layers. To widen the impact of THz-TDS systems, the THz bandwidth should be maximized, ideally exceeding 15 THz

Here, we introduce a hybrid THz-emitter concept based on a spintronic THz emitter (STE) [1] that is deposited onto a thin freestanding GaSe nonlinear crystal. By tuning the parameters of this hybrid emitter and by superimposing the generated THz pulses from the STE and GaSe, we generate an ultrabroadband THz spectrum covering the full range from 1 to 40 THz without any gaps at high spectral amplitudes, resulting in ultrashort THz-pulse durations of only 32 fs.

Finally, we demonstrate a tunability of the carrier-envelope phase by the external magnetic field from unipolar or bipolar THz pulses with ultrashort duration that are well suited as ultrabroadband THz probe pulses.

[1] Seifert, T., Jaiswal, S., Martens, U. et al. Nature Photon. 10 (2016).

15 min. break

MA 24.8 Wed 11:30 EB 202

Rotating spintronic THz emitter for high-power and field-driven applications at MHz repetition rates — •Alkisti Vaitsi[1], Vivien Sleziona[1], Luis E. Parra Lopéz[1], Yannic Behovits[2], Fabian Schulz[3], Natalia Martín Sabanés[4], Tobias Kampfrath[2], Martin Wolf[1], Tom S. Seifert[2], and Melanie Müller[1] — [1]Fritz Haber Institute, Berlin, Germany — [2]Freie Universität Berlin, Berlin, Germany — [3]CIC nanoGUNE, San Sebastian, Spain — [4]IMDEA Nanoscience, Ciudad Universitaria de Cantoblanco, Madrid, Spain

We demonstrate high-power operation of a broadband spintronic terahertz emitter (STE) excited with up to 18 W pump power at MHz repetition rates for THz-field-driven applications. By rotating the STE at angular speed on the order of 100 Hz, we achieve optimal power conversion efficiency at fluences of $\sim 1\ mJ/cm^2$ at average power densities of $\sim 350\ W/cm^2$, well above the laser damage threshold of thin metallic films. The rotating STE design is scalable and eliminates material degradation due to thermal heating. Optimizing further the THz propagation from the rotating STE, we achieve peak THz fields of up to 10 and 6 kV/cm incident on the junction of a THz scanning tunneling microscope at 1 and 2 MHz repetition rate, resulting in $\sim 5\ V$ and 8 V THz bias voltages inside the STM. We discuss performance limiting saturation mechanisms and present an optimal setup design for application of the STE in THz-STM and other field-driven applications.

MA 24.9 Wed 11:45 EB 202

Broadband spintronic terahertz source with peak electric fields exceeding 1.5 MV/cm — •Reza Rouzegar[1,2], Alexander Chekhov[1,2], Yannic Behovits[1,2], Bruno Serrano[1], Maria Syskaki[3], Charles Lambert[4], Dieter Engel[5], Markus Münzenberg[6], Gerhard Jakob[3], Mathis Kläui[3], Tom S. Seifert[1], and Tobias Kampfrath[1,2] — [1]Freie Universität Berlin — [2]Fritz-Haber-Institute of MPG — [3]Johannes Gutenberg University Mainz — [4]ETH Zürich — [5]Max-Born-Institute in Berlin — [6]Universität Greifswald

Spintronic terahertz emitters (STEs) allow one to generate ultrashort terahertz electromagnetic pulses by excitation with a femtosecond laser pulse. Here, we significantly improve the performance of an STE by a factor of up to 6 in field amplitude by optimizing the management of light and heat flow. Our new Si-based STE (Si-STE) design features almost 100% pump absorptance, enhanced terahertz outcoupling and maximized heat-transport into the substrate. Using high energy pump pulses (energy 5 mJ, duration 80 fs, wavelength 800 nm), we generate THz pulses with peak electric fields of 1.5 MV/cm, a fluence of the order of 1 mJ/cm^2, with a gapless spectrum covering the range 1-11 THz. We compared our new Si-STE design to $LiNbO_3$, which is the gold standard of table-top high-power terahertz sources. We find comparable peak fields and fluences. The optimized STE (Si-STE) still has all attractive features of the standard STE, e.g., straightforward rotation of the terahertz polarization plane by an external magnetic field, ease-of-use and independence of the pump wavelength.

MA 24.10 Wed 12:00 EB 202

Broadband spintronic sampling of true terahertz electric fields — •Alexander Chekhov[1], Yannic Behovits[1], Julius Heitz[1], Maria-Andromachi Syskaki[2], Bruno Rosinus Serrano[1], Amon Ruge[1], Jana Kredl[3], Markus Münzenberg[3], Gerhard Jakob[2], Mathias Kläui[2], Tom Seifert[1], and Tobias Kampfrath[1] — [1]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [3]Institut für Physik, Universität Greifswald, 17489 Greifswald, Germany

The increasing bandwidth of intense terahertz (THz) sources demands the development of new methods for the sampling of broadband THz electromagnetic pulses. Here, we demonstrate a spintronic approach to THz-electric-field detection based on measuring the THz spin accumulation that is induced at a ferromagnet/heavy-metal (FM/HM) interface by a THz electric field. To put this scheme to the test, we apply ultrabroadband THz pulses from a spintronic THz emitter to FM|HM stacks and probe the transient optical birefringence. We find that the measured signal has the same shape as the driving THz field without any distortions over the full range of 0.1-12 THz. By studying various FM|HM stacks, we reveal the mechanism behind the observed signals and maximize the detector efficiency. Our work not only provides new opportunities in THz photonics but also new insights into THz spin dynamics at interfaces.

MA 24.11 Wed 12:15 EB 202

Ultrabroadband terahertz time-domain spectroscopy of giant magnetoresistance — •Zdenek Kaspar[1,2], Oliver Gueckstock[1], Bikash Das Mohapatra[3], Tom S. Seifert[1], Georg Schmidt[3], and Tobias Kampfrath[1] — [1]Freie Universität Berlin, Germany — [2]Institute of Physics of the Czech Academy of Sciences, Czech Repiblic — [3]Martin-Luther-Universität Halle-Wittenberg, Germany

We perform broadband terahertz (THz) time-domain spectroscopy on giant magnetoresistance (GMR) stacks F1|Cu(3.2 nm)|F2 where F1, F2 are ferromagnetic metal thin-films with parallel (↑↑) or antiparallel (↑↓) in-plane magnetization. By utilizing ultrashort THz electric-field pulses, we measure the GMR contrast at 1-25 THz in a current-in-plane (CIP) geometry.

Our data reveal a notable decrease of the GMR contrast from 2% to 1.5% from 1 THz to 25 THz. Remarkably, we observe an almost frequency-independent time delay of 15 fs of the GMR response relative to the driving THz field. We attribute this delay to the time required for an electron to propagate through the Cu layer between F1 and F2 and to undergo spin-dependent scattering at the F1|Cu and Cu|F2 interfaces. This notion is supported by experiments, in which we increase/decrease the Cu thickness and observe an increase/decrease of the time delay.

MA 24.12 Wed 12:30 EB 202

Theoretical analysis of the terahertz radiation spin-based sensors design — •Ievgeniia Korniienko[1], Pablo Nieves[1,2], Oksana Chubykalo-Fesenko[3], and Dominik Legut[1] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czech Republic — [2]University of Oviedo, Oviedo, Spain — [3]Instituto de Ciencia de Materiales de Madrid, ICMM-CSIC, Madrid, Spain

In recent years, there has been an increased interest in terahertz (THz) radiation, which is caused on the one hand by the success in creating THz emitters [1], and on the other hand by the potential applications of radiation in this range [2]. Although there is a wide variety of THz detectors they all show sensitivity to the electrical component of THz electromagnetic radiation [3]. THz magnetic field directly couples to the spins by the Zeeman interaction making it possible to detect THz radiation by magnetic dynamics observation. In our work, we theoretically analyze the possibilities to create spin-based detectors that would be sensitive to the magnetic component of THz radiation [4]. We explore the potential capabilities of such sensors, their application limits, and also provide an analysis of potential candidates among ferromagnetic materials. The obtained theoretical dependencies can be useful to reduce the impact of measurement inaccuracies and noises on the THz signal.

[1] T. Seifert, et al.: Nature Photonics 10, 483 (2016). [2] A. Y. Pawar, et al.: Drug Invention Today 5, 157 (2013). [3] S. S. Dhillon, et al.: Journal of Physics D: Applied Physics 50, 043001 (2017). [4] I. Korniienko, et al.: Phys. Rev. Applied (under review).

MA 24.13 Wed 12:45 EB 202

Terahertz detection of magneto-photocurrent in topological insulator Bi_2Se_3 — •Chihun In[1,2], Genaro Bierhance[1,2], Deepti Jain[3], Tom Seifert[1,2], Oliver Gueckstock[1,2], Roberto Mantovan[4], Seongshik Oh[3], and Tobias Kampfrath[1,2] — [1]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany — [2]Department of Physical Chemistry, Fritz Haber Institute of the Max Planck Society, 14195 Berlin, Germany — [3]Department of Physics and Astronomy, Rutgers, The State University of New Jersey, Piscataway, New Jersey 08854, USA — [4]CNR-IMM Unit of Agrate Brianza, Via Olivetti 2, Agrate Brianza, MB 20864, Italy

Femtosecond laser excitation can drive ultrafast photocurrents in topological insulators (TIs) such as Bi_2Se_3. Here, we report THz emission from Bi_2Se_3 thin films by applying a magnetic field of $|\boldsymbol{B}| = 0.3$ T parallel to the film plane. First, we find a pronounced THz emission signal odd in $\boldsymbol{B}$ that changes its sign with $\boldsymbol{B}$. Second, we observe a strong reduction of the THz amplitude as bismuth is substituted by indium. The reduced spin-orbit coupling strength of $(Bi_{1-x}In_x)_2Se_3$ removes the Dirac surface state at a critical concentration of $x = 0.07$. Therefore, the suppressed THz signal of $(Bi_{1-x}In_x)_2Se_3$ for $x > 0.07$ suggests that the Dirac surface state and spin-momentum locking are critical to the emergence of the observed THz magneto-photocurrent. The time dependence of the photocurrent will be extracted, and possible interpretations will be discussed.

MA 24.14 Wed 13:00 EB 202

Magnon terahertz spin transport in metallic Gd|Pt thin-films — •Oliver Gueckstock[1,2], Tim Amrhein[1], Tom S. Seifert[1], Martin Weinelt[1], Tobias Kampfrath[1,2], and Nele Thielemann-Kühn[1] — [1]FU Berlin, Berlin, Germany — [2]FHI Berlin, Berlin, Germany

Transport of spin angular momentum is a fundamental operation required for future spin-electronic devices. To be competitive with other information carriers, it is required to push spin transport to ultrafast time scales [1]. Here, we use femtosecond laser pulses to trigger ultrafast spin transport in prototypical F|N bilayers from a ferromagnetic layer F into a nonmagnetic metal layer N [2]. Following absorption of the pump, a spin current in F is launched and converted into a transverse charge current in N, where it gives rise to the emission of a THz electromagnetic pulse [2]. Two driving forces can occur: (i) a temperature gradient (Seebeck-like effect) [3] and (ii) a spin-voltage gradient [4]. In metallic F, (ii) dominates and relies on conduction electrons, while (i) is found for insulating F [3,4]. Remarkably, in the fully metallic ferromagnet Gd, we find Seebeck-type dynamics and, thus, spin transport due to magnons. This finding highlights the great importance of magnon-mediated spin transport, in particular in metallic systems. References: [1] Vedmedenko et al., J. Phys. D: Appl. Phys. 53, 453001 (2020), [2] T. Seifert et al., Nat. Phot. 10, 483 (2016), [3] T. Seifert et al., Nat. Comm. 9, 2899 (2018), [4] R. Rouzegar et al., Phys. Rev. B 105, 184408 (2022).

MA 25: Magnetic Imaging and Sensors II

Time: Wednesday 9:30–13:00 Location: EB 301

MA 25.1 Wed 9:30 EB 301

Imaging propagating spin waves using NV centers — •Carolina Lüthi[1], Lukas Colombo[1], and Christian Back[1,2] — [1]Physics Department, Technical University of Munich, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Spin waves, also known as magnons, are collective excitations of the magnetic moments in a material. The study of spin waves is essential for understanding the magnetic properties of materials, as well as their potential applications in spintronic devices.

A promising novel platform for investigating spin waves is the nitrogen vacancy (NV) center in diamond, a defect in the diamond lattice consisting of a substitutional nitrogen atom and a missing carbon atom. It exhibits remarkable properties, such as the ability to detect magnetic fields with high sensitivity and spatial resolution, even below opaque materials, making it an ideal candidate for detecting spin waves.

In this talk, we present how NV centers can be employed to measure spin waves by detecting the magnetic stray field fluctuations arising from the oscillations of spins in a magnetic material. As an example material we use the ferrimagnetic insulator yttrium iron garnet, which is of great importance due to its extreme low intrinsic Gilbert damping. By comparing spin wave measurements using NV centers to spin wave imaging done through the well-established time-resolved magneto-optical Kerr effect, we discuss the advantages and limitations of utilizing NV centers as spin wave sensors.

MA 25.2 Wed 9:45 EB 301

Development of an Ultra High Vacuum and Low Temperature Scanning NV Magnetometer — •Sandip Maity[1], Dinesh Pinto[1,2], Ricardo Javier peña Román[1], Klaus Kern[1,2], and Aparajita Singha[1] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Institut de Physique, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

The nanoscale spatial resolution and ambient condition measurement capabilities of nitrogen vacancy (NV) sensors have enabled us to perform magnetic imaging through scanning probe microscopy (SPM) across a wide range of temperature and pressure. I will be discussing the development of a scanning probe magnetometer, capable of imaging magnetic nanostructures with a high spatial resolution under ultra-high vacuum and low temperature (10^{-10} mbar and 4 K) conditions, enabled with an external vector magnetic field (1 T in z and 0.25 T in both x and y direction). Here, NV centers are integrated within diamond tips to perform Atomic Force Microscopy (AFM). We have used NV tips with a home built tip holder equipped with an AFM amplifier and microwave excitations on the tip (not on the sample), allowing us to have a magnetic image of any region of a sample without restriction. Optically Detected Magnetic Resonance (ODMR) using Zeeman splitting can locally quantify the stray magnetic field from a sample. Additionally, the integrated facilities involving UHV and low temperature capabilities will allow us to investigate the stability of the NV probes and the effects of surface modifications at UHV condition, in a highly controlled manner.

MA 25.3 Wed 10:00 EB 301

SOPHIE: A New Soft X-ray Ptychographic Microspectroscopy Endstation — •Tim A. Butcher, Nicholas W. Phillips, Lars Heller, Mirko Holler, Carlos A. F. Vaz, Armin Kleibert, Simone Finizio, and Jörg Raabe — Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

The SOPHIE (SOft X-ray Ptychography Highly Integrated Endstation) endstation, newly developed at the Swiss Light Source (SLS), is designed for microspectroscopy in the soft X-ray range at synchrotrons. This energy range allows elemental and magnetic sensitivity for measurements involving 3d transition metals, which is key for studies in nanomagnetism. Soft X-ray ptychography is able to deliver a spatial resolution in the order of 5 nm, which can be extended to three dimensional imaging in a laminographic geometry. Currently, SOPHIE is located at the SoftiMAX beamline of MAX IV and will be returned to the SIM beamline after the upgrade to SLS 2.0. The first imaging results and the general capabilities of the endstation will be presented during this talk. This includes the successful imaging of non-collinear magnetic order such as the spin cycloid in bismuth ferrite.

MA 25.4 Wed 10:15 EB 301

Third-order magnetooptic Kerr effect in magnetic thin films — Maik Gaerner[1], Robin Silber[2], Jaroslav Hamrle[3], and •Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]Technical University of Ostrava, Czechia — [3]Charles University, Prague, Czechia

The magnetooptic Kerr effect (MOKE) describes the change of polarization when linear polarized light is reflected from a magnetized sample. This enables to study the reversal processes of the magnetization **M**, image magnetic domain patterns or investigate the dynamics of **M** on short time scales. Here, the linear MOKE (LinMOKE) being proportional to **M** is regularly utilized for investigations of ferromagnetic samples while the quadratic MOKE (QMOKE) being proportional to $\mathbf{M}^2$ [1] is the tool to study antiferromagnetic properties and sense the structural order in Heusler compounds [2].

We recently explored the third-order MOKE, so-called cubic MOKE (CMOKE), being proportional to $\mathbf{M}^3$, which depends on the degree of structural domain twinning [3]. The individual MOKE contributions can experimentally be separated by the eight-directional method, i.e. by applying an external magnetic field in various in-plane sample directions for different orientations of the crystal structure. Within this talk, we will introduce the CMOKE and discuss its dependency on twinning properties, materials and crystal orientations. In addition, we will point out potential future applications of CMOKE.

[1] R. Silber et al., Phys. Rev. B 100, 064403 (2019)
[2] R. Silber et al., Appl. Phys. Lett. 116, 262401 (2020)
[3] M. Gaerner et al., arXiv: 2205.08298

MA 25.5 Wed 10:30 EB 301

Introduction to magnetization measurements with high hydrostatic pressure — •Börge Mehlhorn[1], Markus Hücker[2], Laura Teresa Corredor Bohórquez[1], Anja Wolter[1], and Bernd Büchner[1,3] — [1]Leibniz IFW Dresden, D-01069 Dresden, Germany — [2]Weizmann Institute of Science, IL-7610001 Rehovot, Israel — [3]Institute for Solid State and Materials Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, D-01062 Dresden, Germany

Hydrostatic pressure has become an important addition to the variables that can be controlled in the characterization of novel materials. It allows the lattice parameters of a solid material to be altered without doping or exchanging atoms, potentially leading to the tuning of its physical properties. For many characterization methods technical developments like diamond anvil cells have led to the discovery of new properties in many materials, for example high-pressure superconducting states. Those advances are however not easily transferred to bulk magnetization measurements. Not only is the choice of materials for the fabrication of a pressure device limited, its geometry is also greatly constrained. Sample space, resolvable moment and maximum pressure have to be balanced to fit the specific research goals. This talk gives an introduction to the study of magnetization of a sample that is simultaneously exposed to high magnetic field, low temperature and high pressure. An experiment design tuned to resolve very low magnetic moments of the quasi-2D Heisenberg antiferromagnet La_2CuO_4 are presented as an example.

MA 25.6 Wed 10:45 EB 301

Devices for Correcting Phase Aberration in Longitudinal MIEZE at RESEDA — •Luke Jatho[1], Denis Mettus[1], Lukas Beddrich[2], Johanna K. Jochum[2], and Christian Pfleiderer[1,2] — [1]Physik Department, Technische Universität München, Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany

The RESEDA instrument, situated at the FRM II facility, operates as a resonant spin-echo spectrometer utilizing the MIEZE (Modulated Intensity with Zero Effort) technique in a longitudinal geometry. While RESEDA offers access to a broad range of energy scales, its optimal resolution for momentum-transfer vectors is primarily concentrated at small scattering angles. Recent advancements have demonstrated the extension of the accessible scattering angle range through the incorporation of Magnetic Wollaston Prisms (MWPs) [1]. However, MWPs are not suited for longitudinal MIEZE. Consequently, there is a pressing need to develop a similar device capable of providing spatial-intensity modulation capabilities within the L-MIEZE geometry. In this contribution, we explore various magnetic coil configurations designed to generate the required field gradient and present the results of numerical simulations. [1] F. Li, J. Appl. Cryst. (2022). 55, 90-97

MA 25.7 Wed 11:00 EB 301

Portable devices for adding Spatial-Intensity-Modulation-mode capabilities to polarized neutron beams — •Denis Mettus[1], Jonathan Leiner[2], Johanna Jochum[3], Lukas Beddrich[3], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Oak Ridge National Laboratory, Oak Ridge, TN 37830, United States — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany

The Modulated IntEnsity with Zero Effort (MIEZE) resonant spin-echo technique implemented at the RESEDA instrument at the FRM II has its optimum resolution at small scattering angles, i.e. SANS geometries. To extend the application of MIEZE to larger scattering angles, the incorporation of magnetic Wollaston prisms (MWPs) has been suggested which would allow correction of the neutron time of flight differences restoring the signal contrast [1]. In addition to that, MWPs promises to be useful in such applications as measuring diffraction peaks with enhanced resolution at Larmor diffraction instruments, improving the resolution of small angle neutron scattering instruments, or in the context of intra-particle mode-entangled neutron beams for potential use in probing many-body quantum entanglement in materials. In the following contribution, we present the progress of the MWPs construction for use at FRM II, and describe the details of their operation and the various possibilities they offer.

[1] Fankang Li, J. Appl. Cryst. 55, 90-97 (2022).

15 min. break

MA 25.8 Wed 11:30 EB 301

Planar Hall effect sensors enabling improved Magnetic Particle Tracking — •Jan Schmidtpeter, Yevhen Zabila, Denys Makarov, and Thomas Wondrak — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden Germany

Magnetic Particle Tracking is able to track the position and orientation of magnetic particles in opaque media by measuring the magnetic field outside the vessel. This technique was already applied in granular flows with a magnet of 8 mm^3 volume [1]. The extension of this technique to flotation, which is used in ore processing and recycling, requires magnetic particles in sub-mm range, which float with the foam. The vessel diameter of 100 mm demands for sensors with a resolution in the order of nT. Thin-film sensors reduce the distance from the sensor to the magnet. We will present in detail a newly developed measurement system with an array of 12 tailored planar Hall magnetoresistive sensors with a measurement range from 300 μT down to 10 nT and demonstrate the reliable detection of the position of a cubic magnet with edge length of 0.4 mm. The sensors consist of single layer permalloy in a 5 ring Wheatstone bridge configuration. Furthermore, we will show preliminary results of an sensor array on a flexible substrate [2], which can be easily and accurately placed around a complex shaped vessel.

[1] Buist, et al. AIChE Journal 60.9 (2014): 3133-3142.
[2] Granell, et al. npj Flexible Electronics 3.1 (2019): 3.

MA 25.9 Wed 11:45 EB 301

Green transferring of GMR sensors onto arbitrary substrates with loss-free performance and mechanical robustness for interactive electronics — •Olha Bezsmertna[1], Rui Xu[1], Eduardo Sergio Oliveros-Mata[1], Clemens Voigt[2], Sindy Mosch[2], Mykola Vinnichenko[2], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]Fraunhofer Institute for Ceramic Technologies and Systems IKTS, 01277 Dresden, Germany

Recent progress in branch of flexible electronics led to the expansion of its applications in artificial intelligence, the Internet of Things (IoTs), wearable electronics, etc. Flexible magnetic field sensors enable new generation of devices based on touchless interaction [1, 2]. However, integration of highly-sensitive magnetic sensors into non-planar surfaces still remains challenging. Although transfer printing method has been adopted to diversify the applicable substrates, the selection freedom is still limited. We propose a green transfer printing method, capitalizing on the following features: 1) our technique only relies on biocompatible water and does not resort to any additional treatments; 2) sensors can be transferred onto arbitrary substrates without performance degradation; 3) the transferred sensors have robust mechanical stability. Thanks to the above advantages, the magnetic sensors demonstrate promising potentials in on-skin electronics as human-machine interfaces, smart agriculture and household IoTs applications.

[1] Xu, R. et al. Nat. Comm., 13(1), 6587 (2022); [2] Cañón Bermúdez, G. S. et al. Adv. Funct. Mat., 31(39), 2007788 (2021).

MA 25.10 Wed 12:00 EB 301

Eco-sustainable Printed Magnetoresistive Sensors — •Lin Guo, Rui Xu, Eduardo Sergio Oliveros Mata, Xuan Peng, Proloy Taran Das, Xilai Bao, Ihor Veremchuk, Larysa Baraban, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf e.V.,01328 Dresden, Germany

As an important member of printed electronics, printed magnetic sensors have revealed potential in industrial production, consumer electronics, etc, relying on large scale, low cost and high production fabrication[1]. However, the escalated demand and short lifespan for electronics contribute significantly to the accumulation of electronic waste, meanwhile magnetic sensors usually contain hazardous elements. Therefore, there is a growing demand for eco-sustainable printed magnetoresistive sensors. Firstly, we introduced self-healing property to printed magnetoresistance sensors to extend their lifetime[2]. Going a step further, here we designed biocompatible and biodegradable printed magnetic sensors to address the e-waste issues using non-toxic iron particles bonded with edible starch. Benefiting from a completely eco-friendly printing process and food-grade materials, these sensors can be applied not only on conventional substrates but also on surfaces like plants, human skin, and nails, furthermore they demonstrate washability and degradability in aqueous environments. By virtue of these advantages, we demonstrated their application as customized speedometers, IoTs, and human-machine interfaces.

[1]D. Makarov et al, ChemPhysChem 2013, 14, 1771. [2]R. Xu, et al, Nature Communications 2022, 13, 6587.

MA 25.11 Wed 12:15 EB 301

Magnetic field mapping with a GMR sensor array: "An IR-camera analogy" — •Laila Bondzio[1], Torben Tappe[1], Holger Sachs[2], Bernd Rebhorn[2], and Andreas Hütten[1] — [1]Bielefeld University, Bielefeld, Germany — [2]Messtechnik Sachs GmbH, Schorndorf, Germany

Giant Magnetic Resistance multilayer systems of Py/Cu-bilayers exhibit nearly triangular shaped GMR curves with a high sensitivity, which is desirable for sensor applications. With a grid of multiple sensor elements a two dimensional magnetic landscapes can be mapped as changes in a magnetic field with an output image similar to an IR-camera. The challenging aspect for such an application is the necessity to cover a relatively large area of few centimeters with sensor elements. To organize and contact this large number of sensor elements the structures can be sputtered directly onto contacts on a circuit board. Using an optimized buffer system ontop of a not ideal substrate improves the GMR effect and provides a foundation for a CPP (current perpendicular to plane) configuration.

MA 25.12 Wed 12:30 EB 301

Sensing of magnetic excitations in 2D-materials with NV spins — •Hossein Mohammadzadeh, Dominik Maile, and Joachim Ankerhold — Institute for complex quantum systems (ICQ), University of Ulm, Ulm, Germany

Magnetism in two-dimensional (2D) van der Waals (vdW) materials has recently emerged as one of the most promising areas in condensed matter research, with a significant potential for applications ranging from topological magnonics to low-power spintronics, quantum computing, and optical communications [1]. In this talk, we theoretically investigate the possibility of sensing magnetic excitations in such materials with nitrogen-vacancy (NV) center in diamond. The NV center in diamond is an excellent platform for noninvasively detecting nano-scale signatures and magnetic domain walls [2]. We present a description of the low-energy magnetic excitations within a Kitaev-Heisenberg model for a honeycomb lattice. Coupling these excitations to the single NV-electronic spin paves the way to use magnetic noise spectroscopy to probe magnons in such a system. Utilizing Fermi*s golden rule and quantum linear response theory, we show how the spin relaxation time of the NV alters in the magnetic field induced by magnons in both bulk and topologically protected edge states. The relaxation time of the NV changes by different NV-sample distances and in various strengths of spin-spin interactions inside the material. [1] Qing Hua Wang et al., ACS Nano, 16, 5, 6960-7079 (2022)

[2] Jörg Wrachtrup et al. Nat Commun 12, 1989 (2021)

MA 25.13 Wed 12:45 EB 301

Directly mapping of magnetization dynamics in chiral three-dimensional magnetic nano double helices — •Imelda Pamela Morales Fernandez[1], Sandra Ruiz Gomez[1], Claudia Fernandez Gonzalez[1], Elina Zhakina[1], Markus König[1], Aurelio Hierro Rodriguez[2], Simone Finizio[3], Sebastian Wintz[4], Claas Abert[5], Dieter Suess[5], Amalio Fernandez-Pacheco[6], and Claire Donnelly[1] — [1]MPI CPFS, Dresden, Germany — [2]Universidad de Oviedo, Spain — [3]PSI, Switzerland — [4]HZB BESSY II, Germany — [5]University of Vienna, Austria — [6]TUWien, Austria

The expansion of nanomagnetism into the third dimension provides exciting opportunities beyond the physics of planar systems. Here, we experimentally explore the magnetic properties of three-dimensional double-helix (DH) nanostructures, which can host an exotic magnetic configuration featuring pairs of highly coupled domain walls(CDWs). Here we consider the magnetization dynamics on the nanosecond timescale within the 3D-DH nanostructure. Specifically, we harness three-dimensional nanofabrication techniques to manufacture cobalt nano-double-helices onto striplines and subject them to high-frequency magnetic field excitations. Utilizing time-resolved scanning transmission X-ray microscopy, we map the magnetization dynamics on the three-dimensional nanostructure in real space, revealing localized enhanced dynamics in the positions of CDWs within the DH conduit, that depend on the geometry of the nanostructure and the excitation. These initial findings provide exciting insight into the physics and opportunities for the future of 3D magnetization dynamics.

MA 26: Focus Session: Unconventional Thermoelectric Phenomena and Materials (joint session MA/TT)

Thermoelectric effects have been discussed for several decades and have found widespread applications. This Focus Session, a joint venture of the divisions MA (Magnetism) and TT (Low Temperature), will thematise recent developments, namely "unconventional" thermoelectric phenomena and materials [see, e.g., K. Uchida and J. P. Heremans, Joule 6, 2240 (2022)]: these include transverse thermoelectric effects, such as the ordinary and anomalous Nernst effects, where the generated charge current is perpendicular to the temperature gradient. The latter – similar to the anomalous Hall effect – relies on the spin-orbit interaction or on canted spin textures, and ensuing topological electronic structures. Transverse thermoelectricity can be found even without a magnetic field, namely in goniopolar materials (e.g., $NaSnAs_2$). Finally, nano-structured coherent quantum hybrid systems, containing dots as well as normal-conducting and superconducting elements, show remarkable – generally nonlocal – thermoelectric properties.

Coordinators: Ulrich Eckern (University of Augsburg, ulrich.eckern@uni-a.de) Max Hirschberger (The University of Tokyo, hirschberger@ap.t.u-tokyo.ac.jp)

Time: Wednesday 15:00–17:45 Location: H 1058

Invited Talk MA 26.1 Wed 15:00 H 1058

Enhanced Nernst effect in van der Waals tellurides — M. Behnami[1], M. Gillig[1], S. Aswartham[1], G. Shipunov[1], D. Efremov[1], B. R. Piening[1], I. V. Morozov[1], K. Ochkan[1], J. Dufouleur[1], V. Kocsis[1], C. Hess[1,5], M. Putti[4,6], F. Caglieris[1,4], B. Büchner[1,2], and •H. Reichlova[1,2,3] — [1]IFW Dresden, Germany — [2]IFMP, Technische Universität Dresden, Dresden, Germany — [3]Institute of Physics ASCR, Praha, Czech Republic — [4]CNR-SPIN, Genova, Italy — [5]Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Germany — [6]Department of Physics, University of Genova, Italy

The increase in the Nernst effect and its anomalous component in magnetically ordered materials is actively researched, and I will start the talk with a brief overview of these efforts. Subsequently, I focus on layered van der Waals materials, which have garnered significant attention in current research due to their distinct properties not inherent in bulk compounds. Particularly intriguing are the topologically non-trivial telluride van der Waals type-II Weyl semimetals with substantial spin-orbit coupling. I will present a systematic exploration of the Nernst effect in this family of materials. We identified a large linear segment of the Nernst coefficient that scales with mobility; however, it does not conform to the previously reported Fermi liquid framework.

Invited Talk MA 26.2 Wed 15:30 H 1058

Hybrid transverse magneto-thermoelectric cooling in artificially tilted multilayers — •Ken-ichi Uchida — National Institute for Materials Science, Tsukuba, Japan

In artificially tilted multilayers comprising two different conductors that are alternately and obliquely stacked, transverse thermoelectric conversion occurs, in which charge and heat currents are interconverted in the orthogonal direction. Although transverse thermoelectric conversion also occurs in homogeneous materials as intrinsic transport phenomena owing to the effects of magnetic fields, magnetization, and spins on conduction carriers, such magneto-thermoelectric effects have been investigated independently of thermoelectrics for artificially tilted multilayers. Here, we show that the synergy of these different principles improves the performance of transverse thermoelectric conversion. Using lock-in thermography techniques, we visualize transverse thermoelectric conversion processes in artificially tilted multilayers and experimentally clarify how nonuniform charge currents are converted into orthogonal heat currents. Through the measurements of temperature change under magnetic fields, we quantify the contributions of the magneto-thermoelectric effects in the artificially tilted multilayers and demonstrate magnetically enhanced hybrid transverse thermoelectric cooling. By replacing one of the conductors in the multilayer with permanent magnets, the same functionality is obtained even in the absence of magnetic fields, paving the way for the creation of thermoelectric permanent magnets. This study provides a new material design guideline for transverse thermoelectrics.

Invited Talk MA 26.3 Wed 16:00 H 1058

Nonlocal heat engines with hybrid quantum dot systems — •Rafael Sánchez[1], Mojtaba S. Tabatabaei[2], David Sánchez[3], and Alfredo Levy Yeyati[1] — [1]Dep. Física teórica de la materia condensada and Ifimac, Universidad Autónoma de Madrid, Madrid, Spain — [2]Department of Physics, Kharazmi University, Tehran, Iran — [3]Institute for Cross-Disciplinary Physics and Complex Systems IFISC (UIB-CSIC), Palma de Mallorca, Spain

The energy absorbed by a conductor from a non-equilibrium environment can be rectified to generate finite electrical power. Typically, this depends on tiny energy-dependent asymmetries of the device, formed by e.g. a quantum dot [1]. We show that larger currents are expected in hybrid systems, where a superconductor hybridizes the even-parity states in the quantum dot [2]. We consider the environment to consist on a quantum dot Coulomb-coupled to the conductor and tunnel-coupled to a hot reservoir. Two main mechanisms contribute to the generation of power. On one hand, the non-equilibrium charge fluctuations in the second dot correlate with the Andreev processes, hence injecting Cooper pairs in the superconductor. This provides the necessary symmetry breaking energy transfer. On the other hand, this mechanism competes with quasiparticle contributions, which benefit from the sharp features of the superconducting density of states, and is able to increase the engine performance [3].

[1] H. Thierschmann et al., Nature Nanotech. 10, 854 (2015)
[2] S. M. Tabatabaei et al., Phys. Rev. Lett. 125, 247701 (2020)
[3] S. M. Tabatabaei et al., Phys. Rev. B 106, 115419 (2022)

15 min. break

Invited Talk MA 26.4 Wed 16:45 H 1058

Large anomalous Nernst thermoelectric performance in $YbMnBi_2$ — •Yu Pan[1,2], Congcong Le[2], Bin He[2], Sarah Watzman[3,4], Mengyu Yao[2], Johannes Gooth[2], Joseph Heremans[3], Yan Sun[2], and Claudia Felser[2] — [1]Chongqing University, Chongqing, China — [2]Max Planck Insitute for Chemical Physics of Solids, Dresden, Germany — [3]The Ohio University, Columbus, USA — [4]University of Cincinnati, Cincinnati, USA

The anomalous Nernst effect (ANE) have attracted increasing attention since the surge of topological semimetals, because the associated unique transverse geometry of ANE facilitates thermoelectric device fabrication. Topological ferromagnets with large Berry curvatures show large ANEs; however, they face drawbacks such as strong magnetic disturbances and low mobility due to high magnetization. Searching for materials with large ANE thermopower, low resistivity (high mobility), and low thermal conductivity are of great interest. It is found that $YbMnBi_2$, as a canted antiferromagnet, present a large ANE competitive to those of ferromagnets while with much lower resistivity and thermal conductivity. The canted spin structure of Mn guarantees a non-zero Berry curvature, but generates only a weak magnetization three orders of magnitude lower than that of general ferromagnets. The heavy Bi with a large spin-orbit coupling enables a large ANE and low thermal conductivity, whereas its highly dispersive $p_{x/y}$ orbitals ensure low resistivity. These results suggest $YbMnBi_2$ as an excellent candidate for transverse thermoelectrics.

Invited Talk MA 26.5 Wed 17:15 H 1058

A path to suistainable and scalable production of high-performance thermoelectric materials — •Maria Ibáñez — Institute of Science and Technology Austria, Am Campus 1, Klosterneuburg, Austria

Over the past few years, there has been a significant surge in interest surrounding solution-based techniques due to their cost-effectiveness and scalability in the production of high-performance thermoelectric materials. Herein, our primary focus will be on Ag_2Se, an important thermoelectric material for harnessing thermoelectricity at or near room temperature, an area where the selection of high-performing materials is currently limited. While Ag_2Se shows great promise, the main problems are the large discrepancy in the reported properties. These discrepancies often stem from the intricate control of defects within the material, such as vacancies, interstitial atoms, dislocations, grain boundaries, and precipitates. We will show that our solution-based synthesis method enables precise defect control, especially avoiding fluctuations in stoichiometry. Additionally, we will illustrate how we can fine-tune microstructural defects, including strain, dislocations, and grain boundary density, leveraging the characteristic phase transition of Ag_2Se during the sintering process. Our results will highlight that besides stoichiometry, the microstructure is crucial for tuning Ag_2Se transport properties. Furthermore, we will highlight the sustainability and scalability of our approach, where solvents can be reused and energy consumption minimized, contributing to a more environmentally friendly production process.

MA 27: Frustrated Magnets I

Time: Wednesday 15:00–18:30 Location: H 2013

MA 27.1 Wed 15:00 H 2013

Spin-wave dynamics in rouaite, $Cu_2(NO_3)(OD)_3$ — •Dmytro S. Inosov[1], Aswathi M. Chakkingal[1], Anton A. Kulbakov[1], J. Ross Stewart[2], and Darren C. Peets[1] — [1]Institut für Festkörper- und Materialphysik, Fakultät Physik, TU Dresden — [2]ISIS neutron source, Rutherford Appleton Laboratory, UK

$Cu_2(NO_3)(OH)_3$ (mineral name: rouaite) is a quasi-1D quantum spin system with structural similarity to botallackite, in which spinon-magnon mixing has recently been reported by H. Zhang *et al.* [Phys. Rev. Lett. **125** (2020), 037204]. It contains highly distorted triangular-lattice layers composed of alternating ferro- and antiferromagnetic spin-$\frac{1}{2}$ chains. The magnetic excitation spectrum of synthetic deuterated $Cu_2(NO_3)(OD)_3$ single crystals, measured by inelastic neutron scattering, reveals collective excitations with magnon bandwidths of ∼11, 1.3 and 0.05 meV in the intrachain, interchain and interlayer directions, respectively, and a spin gap of 0.2 meV. This suggests a hierarchy of exchange interactions at the boundary between quasi-1D and quasi-2D spin systems: While interchain interactions are apparently sufficient to suppress the spinon continuum, some spin-wave branches still show anomalous broadening, reminiscent of the fractionalized behavior in 1D spin chains.

MA 27.2 Wed 15:15 H 2013

Raman scattering of spin-$\frac{1}{2}$ mixed dimensionalities antiferromagnet: α-$Cu_2V_2O_7$ — •Arvind Kumar Yogi[1], Hemant Singh Kunwar[1], Isha Isha[1], Binoy Krishna De[1], Vivek Dwij[2], Mayanak Kumar Gupta[3], R. Mittal[3], R. Venkatesh[1], R. J. Chaudhary[1], Mahesh Vedpathak[4], and V. G. Sathe[1] — [1]UGC-DAE Consortium for Scientific Research, University Campus, Khandwa Road, Indore-452001, India — [2]Department of Condensed Matter Physics and Material Science, Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai-400005,India — [3]Solid State Physics Division, Bhabha Atomic Research Centre, Trombey, Mumbai-400005, India — [4]Department of Physics, Vidya Pratishthan's Arts, Science and Commerce, Baramati-413133, India

We present a detailed investigation of the lattice vibrations and magnetic properties of the spin-$\frac{1}{2}$ α-$Cu_2V_2O_7$ system by means of x-ray diffraction (XRD), magnetic susceptibility, specific heat, x-ray absorption spectroscopy (XAS), x-ray photoelectron spectroscopy (XPS), and Raman scattering measurements along with a phonon structure calculations by density-functional theory (DFT). Thermodynamic measurements show a long-range ordered (LRO) state at Néel temperature $T_N \sim 33.4$ K. The spin-lattice coupling constant of spin-$\frac{1}{2}$ α-$Cu_2V_2O_7$ has been calculated for various phonon modes. Despite exchange coupling in 1D chains, the susceptibility, low-temperature heat-capacity and Raman spectroscopic analysis confirms the antiferromagnetic order emerges from the mixed dimensionality nature of the exchange couplings.

MA 27.3 Wed 15:30 H 2013

Emergent quantum criticality in an Ising spin-1/2 zigzag chain antiferromagnet: $CaCoV_2O_7$ — •Arvind Kumar Yogi[1], Koushik Chakraborty[1], Isha Isha[1], A. K. Bera[2], and M. Isobe[3] — [1]UGC-DAE Consortium for Scientific Research, Indore-452001, India — [2]Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

We report on a quantum critical behavior in the quasi-1D spin-1/2 zigzag frustrated chain antiferromagnet $CaCoV_2O_7$, induced by an applied magnetic field. Below $T_N = 3.3$ K our zero-field neutron diffraction studies reveled the up-up-down-down spin structure, stabilized by an order-by-disorder phenomenon. At base temperature, the magnetic order is suppressed by an applied magnetic field (B), inducing a transition into a quantum paramagnetic state at $B_c = 3$ T, as revealed by both neutron diffraction and ESR data. The transition exhibits an unusually sharp phase boundary with the critical exponent $\phi = 0.164(3) \approx 1/6$, in contrast to the earlier experimental observations for uniform spin-1/2 chain systems. Such a sharp QPT is anticipated due to the spin frustration arising from the competing NN and NNN exchange interactions J_1 and J_2 of the zigzag spin chain.

MA 27.4 Wed 15:45 H 2013

On the origin of correlated diffuse scattering in the hexagonal manganites — •Tara Tošić[1], Arkadiy Simonov[2], and Nicola Spaldin[1] — [1]Materials Theory, ETH Zürich, Switzerland — [2]Disordered Materials, ETH Zürich, Switzerland

Using symmetry analysis, first-principles density functional theory and spin dynamics, we pinpoint the origin of the correlated diffuse neutron scattering in hexagonal yttrium manganite (h-$YMnO_3$). We show that the observed directionality in the structured diffuse scattering in momentum space is a hallmark of the triangular geometry, and that its persistence across a wide range of temperatures, both above and below the Néel temperature, T_N, is a result of the strong magnetic frustration. We argue that excitations away from the magnetic ground state - a scenario ruled out in previous modelling attempts - give rise to short-range correlations. Though a hierarchy of nearest-neighbor exchanges and magnetic anisotropy terms, clusters of ordered spins form and interact with each other, creating excitations. We also visualize the magnetic order in terms of composite trimer magnetoelectric monopoles and toroidal moments, rather than individual spins, providing insight into the real space fluctuations, revealing clusters of emerging order in the paramagnetic state, as well as collective short-range excitations in the ordered Néel phase. Our understanding of this directional diffuse scattering both below and above T_N provides new insight into the magnetic phase transitions in frustrated systems.

MA 27.5 Wed 16:00 H 2013

Superparamagnetic behavior of magnetically frustrated rare earth element substituted R-type hexagonal ferrite suitable for biomedical applications — •Imran Sadiq — University of the Punjab, Lahore, Pakistan

This research article reported the inducement of frustration with the substitution of rare earth elements in already frustrated R-type hexagonal ferrites. Crystallographic X-ray diffraction refinement gave the evidence that all the samples display the single phase hexagonal structure with space group P63/mmc. The lattice parameter varied as concentrations increased. The particle sizes measured from TEM and HR-TEM was found to vary in the range of 10-15 nm. These nanoparticles are spherical in shape and exhibit single magnetic domain. The particle size is an excellent agreement with the crystalline size. VSM results revealed its superparamagnetic nature. This frustration turned the magnetic phase of the material from ferrimagnetic to superparamagnetic. It does not have appreciable magnetic hysteresis loop due to zero coercivity and have a negligible values of remanence and squareness ratio revealed its single magnetic domain. The hysteresis loops were fitted theoretically using Langevin function and were in good agreement with experimental results. These materials with almost negligible intrinsic magnetization are suitable for biomedical application especially targeted drugs delivery.

MA 27.6 Wed 16:15 H 2013

Frustrated triangular magnetism in new copper based single crystals — •Aswathi Mannathanath Chakkingal[1], Chloe Fuller Fuller[2], Dmitry Chernyshov[2], Maxim Avdeev[3], Marein Christopher Rahn[1], Yiran Wang[4], Falk Pabst[4], Thomas Doert[4], Darren Peets[1], and Dmytro Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]ESRF, Grenoble, France — [3]ANSTO, Sydney, Australia — [4]Professur f. Anorganische Chemie II, TU Dresden, Germany

The hydrothermal technique is an efficient strategy to synthesize mineralogically inspired structures, including natural and synthetic cuprate minerals with a variety of exciting frustrated magnetic lattices. We report the hydrothermal synthesis of single crystals of a new material $Cu_4(SO_4)(OH)_6$. Single-crystal x-ray and neutron diffraction studies performed to determine the crystal structure reveal the presence of three copper layers which stack in an ABACABAC pattern in the crystal, which results in a large b lattice constant of 25Å. Distorted and expanded $SO_4{}^{2-}$ tetrahedra are identified in the system, likely due to vacancies. The Cu^{2+} copper ions are arranged in buckled sheets consisting of ribbons of edge-sharing and corner-sharing octahedra, and form a heavily distorted triangular lattice. Diffuse scattering measured with synchrotron x-rays also reveals strong stacking-fault disorder in this system. We report details of the crystal structure and its low temperature magnetic properties.

MA 27.7 Wed 16:30 H 2013

Investigation of the magnetoelectric and magnetoelastic properties of the quantum spin liquid candidate $Na_2Co_2TeO_6$ — •Vilmos Kocsis[1], Sven Luther[2], Nicolás Pérez[1], Weiliang Yao[3], Hannes Kühne[2], Anja U. B. Wolter[1], Yuan Li[3], and Bernd Büchner[1] — [1]IFW-Dresden, Dresden, Germany — [2]HZDR, Dresden, Germany — [3]Peking University, Bejing, China

Due to the promising features for quantum computing technologies, the exactly solvable Kitaev model with its bond-dependent interactions has attracted large attention in the scientific community. However, so far there is no such real crystalline material which provides a purely bond-dependent realization of the Kitaev model, as all candidate materials have significant exchange interactions and long-range magnetic order as a result. While these direct exchange interactions are undesirable, they also offer unique possibilities to suppress the long-range order. As an example, the magnetoelastic coupling in some Heisenberg-Kitaev magnets is suggested to be used to suppress the long-range AFM order via uniaxial stress. Here we discuss the magnetoelastic and magnetoelectric properties of the quantum spin liquid candidate $Na_2Co_2TeO_6$. We study the phase diagram of $Na_2Co_2TeO_6$ using thermodynamic, magnetic, magnetoelastic, and magnetoelectric measurements. We find strong magnetoelastic and moderate magnetoelectric response responses, magnetostriction is particularly strong for in-plane fields. We contemplate the possibility of using magnetoelectricity in Heisenberg-Kitaev magnets as a new, unique way to extinguish the unwanted long-range order.

15 min. break

MA 27.8 Wed 17:00 H 2013

Frustrated triangular magnetism in new copper based single crystals — •Aswathi Mannathanath Chakkingal[1], Chloe Fuller Fuller[2], Dmitry Chernyshov[2], Maxim Avdeev[3], Marein Christopher Rahn[1], Yiran Wang[4], Falk Pabst[4], Thomas Doert[4], Darren Peets[1], and Dmytro Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]ESRF, Grenoble, France — [3]ANSTO, Sydney, Australia — [4]Professur f. Anorganische Chemie II, TU Dresden, Germany

The hydrothermal technique is an efficient strategy to synthesize mineralogically inspired structures, including natural and synthetic cuprate minerals with a variety of exciting frustrated magnetic lattices. We report the hydrothermal synthesis of single crystals of a new material $Cu_4(SO_4)(OH)_6$. Single-crystal x-ray and neutron diffraction studies performed to determine the crystal structure reveal the presence of three copper layers which stack in an ABACABAC pattern in the crystal, which results in a large b lattice constant of 25Å. Distorted and expanded $SO_4{}^{2-}$ tetrahedra are identified in the system, likely due to vacancies. The Cu^{2+} copper ions are arranged in buckled sheets consisting of ribbons of edge-sharing and corner-sharing octahedra, and form a heavily distorted triangular lattice. Diffuse scattering measured with synchrotron x-rays also reveals strong stacking-fault disorder in this system. We report details of the crystal structure and its low temperature magnetic properties.

MA 27.9 Wed 17:15 H 2013

Towards a diagrammatic approach to quantum spins — •Björn Sbierski — Universität Tübingen, Germany

Frustrated quantum spin systems in high dimension are one of the central challenges for numerical approaches to quantum many body physics. In this situation a diagrammatic approach based on a pseudofermion or pseudo-Majorana spin representation and resummation by the functional renormalization group have provided useful results. However, as two fermions are required to form a single spin operator, this approach lacks efficiency and cannot access spin correlators beyond the two-point object. We present progress towards an alternative diagrammatic approach that directly works with correlation functions of spin operators without any intervening representation of the latter and can also deal with arbitrary spin length S. We discuss the basic diagrammatic rules, definition of vertex ireducibility and various resummation schemes. We present benchmarks of this method and also study spin Hamiltonians of current relevance.

MA 27.10 Wed 17:30 H 2013

Magnetic interaction and anisotropy in frustrated $GdInO_3$ probed by electron spin resonance spectroscopy — •Luca Bischof[1], Rahel Ohlendorf[1], Ning Yuan[1], Hans-Albrecht Krug von Nidda[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany

Rare earth (R) ions on a triangular lattice as in the ferroelectric $RInO_3$ have recently emerged as a great possibility to study the physics of magnetically frustrated systems. Here we report X- and Q-band electron spin resonance spectroscopy probing the spin-only magnetism of single-crystal [1] gadolinium indate $GdInO_3$. Temperature- and angle-dependence of the observed paramagnetic resonance reveal anisotropic magnetic behavior of the system. We find weak single-ion anisotropy ($|D| \approx 4$ GHz) of the Gd-spins using a combined line-width analysis of angular dependencies in X- and Q-band data under consideration of the 10/3-effect. Our data further allow us to quantify the strength of dipolar and isotropic exchange interactions showing that the latter dominantly governs the spin dynamics in $GdInO_3$.

[1] N. Yuan et al., Phys. Rev. B 108, 224403 (2023).

MA 27.11 Wed 17:45 H 2013

Constructing Emergent U(1) Symmetries in the Gamma-Prime model — •Sagar Ramchandani[1], Simon Trebst[1], and Ciarán Hickey[1,2,3] — [1]Institute for Theoretical Physics, University of Cologne — [2]School of Physics, University College Dublin, Belfield, Dublin — [3]Centre for Quantum Engineering, Science, and Technology, University College Dublin

Frustrated magnets can elude the paradigm of spontaneous symmetry breaking and exhibit emergent symmetries at low temperatures. Here we study such an emergent symmetry in a classical spin model whose underlying Hamiltonian actually has very little symmetry, a bond-directional, off-diagonal exchange model inspired by the microscopics of spin-orbit entangled materials (the Gamma-prime model). Surprisingly, the ground state possesses an emergent, continuous U(1) symmetry for a wide variety of lattice geometries with triangular motifs, such as the kagome or hyperkagome lattices. We discuss a thermal order-by-disorder effect which leads to the formation of a Z_6 symmetric phase at the lowest temperatures. Using Monte Carlo simulations, we explore the model's full finite temperature phase diagram and connect its dependence on spatial dimension (2d versus 3d) to known renormalization group results. Finally we comment on the fate of the model in the quantum spin-1/2 limit.

MA 27.12 Wed 18:00 H 2013

Magnetism in the 3D face-centred frustrated spin-$\frac{5}{2}$ system $MnSn(OH)_6$ — •Kaushick K. Parui[1], Anton A. Kulbakov[1], Roman Gumeniuk[2], Maxim Avdeev[3,4], Darren C. Peets[1], and Dmytro S. Inosov[1] — [1]IFMP, Technische Universität Dresden, 01069 Dresden, Germany — [2]Institut für Experimentelle Physik, TU Bergakademie Freiberg, 09596 Freiberg, Germany — [3]ANSTO, Lucas Heights, NSW 2234, Australia — [4]School of Chemistry, The University of Sydney, Sydney 2006, Australia

Manganese tin hydroxide, $MnSn(OH)_6$ is an *A*-site-vacant double perovskite with the general stoichiometry $\square_2(BB')(OH)_6$, where B and B' are transition metals. Here, the magnetic Mn^{2+} ions sit on a face-centred sublattice, which makes the system frustrated and is expected to exhibit exotic magnetism. The structure is characterized by the presence of alternating corner-linked $[Mn^{2+}(OH)_6]$ and $[Sn^{4+}(OH)_6]$ octahedra. Our magnetization measurements reveal the Curie-Weiss temperature of −5.13(1) K, indicating antiferromagnetic interactions, and a paramagnetic moment of $\approx 5.6\mu_B$. Despite that, specific heat measurements do not show any sharp magnetic transitions down to 350 mK. This suppression of the magnetic order hints towards a large frustration factor >10. We also report the results of neutron diffraction measurements down to 20 mK and structure refinements based on x-ray and neutron powder diffraction data.

MA 27.13 Wed 18:15 H 2013

Higher-order exchange driven noncoplanar magnetic state and large anomalous Hall effects in kagome magnet — •Charanpreet Singh[1,2], Sk Jamaluddin[2], Ashis K. Nandy[2], Masashi Tokunaga[3], Maxim Avdeev[4], and Ajaya K. Nayak[2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]School of Physical Sciences, National Institute of Science Education and Research, Jatni-752050, India — [3]The Institute for Solid-State Physics, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8581, Japan — [4]Australian Nuclear Science and Technology Organisation, New Illawarra Road, Lucas Heights, New South Wales 2234, Australia

The noncollinear kagome antiferromagnet Mn_3Sn breaks time reversal symmetry due to the cluster octupole order present in this system. We show that electron doping can induce a noncoplanar magnetic state in Mn_3Sn, which is driven by higher-order exchange interactions and confirmed by our neutron diffraction measurements. The resultant noncoplanar state exhibits a highly tunable scalar spin chirality (SSC) and generates a unique anomalous Hall signal, distinct from the previously examined octupole order-induced Hall signal in this sample. This introduces a novel dual-order phenomenon, where both cluster octupole order and SSC independently contribute to distinct Hall signals. Importantly, the independent manipulation of these orders is demonstrated. Our results open up new possibilities to explore phenomena associated with multiple orders in frustrated magnets.

MA 28: Thin Films: Magnetic Anisotropy

Time: Wednesday 15:00–17:00 Location: EB 107

MA 28.1 Wed 15:00 EB 107

Surface Anisotropy in (110) Epitaxial Complex Oxide Thin Films — •Katharina Lasinger[1,2], Yixuan Song[1], Geoffrey S. D. Beach[1], and Caroline A. Ross[1] — [1]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139, USA — [2]Department of Materials, ETH Zurich, CH-8093 Zurich, Switzerland

The demand for ever increasing density, and hence reduced dimensions, leads to a dominance of surface properties over their bulk counterparts in nano-scale magnetic devices. Spatial inversion symmetry is naturally broken at surfaces and interfaces. Surfaces on low symmetry planes, such as (110), can lead to a further in-plane anisotropic contribution. Using spin-Hall magnetoresistance measurements, we determine the in-plane and out-of-plane uniaxial anisotropy energies for a thickness series (5 - 50 nm) of europium iron garnet and thulium iron garnet epitaxially grown on a (110) gadolinium gallium substrate. We observe a large thickness dependence of the in-plane anisotropy energy, where the surface anisotropy energy is of the same sign and comparable in magnitude to the bulk value. Complex anisotropy landscapes can be tuned to act as a platform for enabling rich spin textures and dynamics [1,2] by taking advantage of the thickness and temperature dependence demonstrated in this work.

(Our Work: "Sizable In-Plane Surface Anisotropy in a (110) Epitaxial Complex Oxide Thin Film", about to be submitted.)

[1] O. R. Sulymenko, et al., Phys. Rev. Appl., 8(6), 064007, 2017.
[2] Y. Zhou, et al., Phys. Rev. Appl., 13(6), 064051, 2020.

MA 28.2 Wed 15:15 EB 107

Tuning perpendicular magnetic anisotropy via hydrogen concentration — Madeleine Bischoff[1], Olav Hellwig[2,3], Karin Leistner[1], and •Markus Gössler[1] — [1]Institute of Chemistry, Chemnitz University of Technology — [2]Institute of Physics, Chemnitz University of Technology — [3]HZDR Dresden-Rossendorf

A strong perpendicular anisotropy is crucial for modern magnetic data storage devices, providing two stable magnetization directions on a bit scale. Post deposition control of this anisotropy via voltage, promises a drastic improvement of the energy-efficiency for the writing process in such devices. Here, we investigate electrochemical hydrogen-loading in aqueous electrolytes as a voltage-controlled magneto-ionic method[1] for the modulation of anisotropy in perpendicularly magnetized Co/Pd multilayers. Using both in situ electrochemical Kerr microscopy and flow-cell coulometry, we can measure coercivity directly as a function of hydrogen concentration. We find a continuous increase of coercivity up to 20% at a concentration smaller than 0.3 hydrogen atoms per metal atom, which we attribute to hydrogen-induced changes in the anisotropy. Our findings agree with recent DFT predictions of hydrogen in Co/Pd[2]. We argue that the degree of intermixing between Co and Pd atoms during sputter deposition determines the maximum attainable hydrogen concentration in our films and therefore the maximum anisotropy change. Our work highlights the importance of the concentration in ionic devices, which has previously been neglected in the magneto-ionic literature. [1] M. Gößler et al., Small 15, 1904523 (2019) [2] K. Klyukin et al., Phys. Rev. Mater. 4, 104416 (2020)

MA 28.3 Wed 15:30 EB 107

Tailoring the Magnetoionic Effect in Magnetic Thin Films through Defect Engineering — •Arne Vereijken[1], Ben Billinger[2], Dimitri Sharikow[1], Markus Gössler[2], Christian Janzen[1], Karin Leistner[2], and Arno Ehresmann[1] — [1]Institute of Physics and CINSaT, University of Kassel, Germany — [2]Institute of Chemistry, University of Technology Chemnitz, Germany

The field of magnetoionics presents a promising approach for energy-efficient and reversible switching behavior in magnetic thin film systems, including but not limited to exchange bias samples and ferromagnetic thin films[1]. Harnessing the magnetoionic effect locally holds potential for structuring artificial domain landscapes, with applications including, among others, domain-wall logic[2,3] and magnet-based lab-on-a-chip technologies[2]. In a systematic study, various defect introduction strategies are explored to understand their influence on magnetoionic modification in magnetic thin film systems. The focus is on adjusting the growth parameters to control the distribution of grain sizes and, consequently, grain boundaries, anticipating enhanced effective, reactive surface area of a ferromagnetic thin film and increased magnetoionic effect. Similarily, we investigate how defects, induced by keV light ion bombardment, impact the magnetoionic effect. This dual microstructural approach aims to advance our understanding of mechanisms and parameters driving the magnetoionic effect.[1] J. Zehner et al., Adv. Electron. Mater. 5, (2019), 5, 1900296 [2] N. Leo et al., Nature 560, (2018), 466*470 [3] D. Holzinger et al., ACS Nano 9, (2015), 7, 7323*7331

MA 28.4 Wed 15:45 EB 107

Spin Wave Modes in YIG Thin Films with Perpendicular Magnetic Anisotropy — •Zeynep Reyhan Öztürk[1] and Fikret Yildiz[2] — [1]SESAME, Amman, Jordan — [2]Gebze Technical University, Kocaeli, Türkiye

This study investigates the importance of magnetic anisotropy in advancing magnetic memory and logic applications, particularly focusing on achieving perpendicular magnetic anisotropy (PMA) in thick ferrimagnetic films using Yttrium Iron Garnet (YIG).

YIG, known for its unique properties in spintronics and magnonics, was utilized to deposit textured crystalline thin films on Si (100) substrates through Pulsed Laser Deposition. Successful realization of PMA, especially in films around 100 nm thick, was attributed to compressive strain at the Si/YIG interface induced by lattice mismatch. The study's in-depth analysis revealed multiple spin wave modes, with the estimated exchange stiffness constant for YIG films. Noteworthy is the rare coexistence of spin wave modes with PMA in YIG thin films up to 120 nm.

These findings contribute significantly to advanced magnonics and insulating spintronics. Importantly, the study achieved PMA without additional layering or doping on silicon substrates, offering a cost-effective and compatible fabrication process. Ongoing experiments, such as XMCD measurements, aim to explore strain-induced anisotropy and the spatial distribution of spin-polarized electrons in YIG films for faster spin wave computing devices and advanced magnonic logic applications.

MA 28.5 Wed 16:00 EB 107

Influence of cap layer material and deposition pressure on the perpendicular magnetic anisotropy in Co/Pt and CoFeB/Pt multilayers — •Raphael Kohlstedt[1], Rico Ehrler[1], Peter Heinig[1,2], and Olav Hellwig[1,2] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany

Co/Pt magnetic multilayers (MLs) often serve as perpendicular magnetic anisotropy (PMA) model systems for magnetic data storage. Concerning dynamic applications CoFeB based MLs received much interest because of their smooth growth and because of the low intrinsic magnetic damping in magnetically soft CoFeB in-plane single layers, which opened up possibilities for new applications [1, 2]. Often PMA ML systems are protected from oxidation by a cap layer, which usually does not attract much attention. Nevertheless, if the CL makes up a significant part of the whole film thickness or is in direct contact with the magnetic material there are a few important things to consider when choosing the material and the deposition pressure. In this study, the influence of the CL on $[Co/Pt]_X$ and $[CoFeB/Pt]_X$ (X. . . repetition number) by varying the material and the deposition pressure is investigated. The effect of interdiffusion of the cap layer material in highly out-of-plane textured (Co/Pt) and polycrystalline towards amorphous (CoFeB/Pt) MLs is presented using XRD, XRR, and magnetometry.

[1] D. Wang et al. IEEE Trans. Magn., 40(4), 2004
[2] von Korff Schmising et al. Phys. rev. res., 5(1), 2023

MA 28.6 Wed 16:15 EB 107

Understanding the collective out-of-plane magnetization reversal in tilted stripe domain systems via a single point of irreversibility — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Gauravkumar Patel[1], Attila Kákay[1], Nikolai S. Kiselev[4], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE — [4]Forschungszentrum Jülich

Perpendicular anisotropy thin film systems are well known for their periodic magnetic stripe domain structures. In this study, we focus on investigating the behavior of $[Co(3.0\ nm)/Pt(0.6\ nm)]_X$ multilayers within the transitional regime from preferred in-plane (IP) to out-of-plane (OOP) magnetization orientation, particularly, we examine the sample with $X = 11$ repetitions, which exhibits a remanent state characterized by a significant presence of both OOP and IP magnetization components, here referred to as the "tilted" stripe domain state*. Using vibrating sample magnetometry, magnetic force microscopy and micromagnetic simulations we investigate this specific sample and find an unusual OOP field reversal behavior via a remanent parallel stripe domain state and a single point of irreversibility. While the reversal via distinct points of irreversibility is qualitatively similar to that of a nano-sized Stoner Wohlfarth particle or a vortex reversal in a micron-sized IP magnetized disk, our system is macroscopic. Finally, we show that this characteristic behavior is a rather general feature of transitional IP to OOP systems.

*[L. Fallarino et al., Phys. Rev. B 99, 024431 (2019)]

MA 28.7 Wed 16:30 EB 107

Disclosing the hidden properties of thin cobalt films with mixed hcp and fcc phases — •G. Patel[1,2], F. Ganss[1], R. Salikhov[1], S. Stienen[1], L. Fallarino[3], R. Ehrler[4], R. Gallardo[5], O. Hellwig[1,4], K. Lenz[1], and J. Lindner[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Dresden University of Technology, Germany — [3]CIC energiGUNE, Spain — [4]Chemnitz University of Technology, Germany — [5]Universidad Tecnica Federico Santa Maria, Chile

Cobalt is a magnetic material that finds extensive use in various applications, ranging from magnetic storage to ultrafast spintronics. Usually, it exists in two phases with hexagonal close-packed (hcp) or face-centered cubic (fcc) crystal structure. The crystal structure of Co films significantly influences their magnetic and spintronic properties. The ratio of the two Co phases has a significant influence on their magnetic properties, indicating that a seemingly simple material can be rather complex in real samples. We report on the thickness dependence of the structural and magnetic properties of sputter-deposited Co on a Pt seed layer. It grows in an hcp lattice at low thicknesses, while for thicker films, it becomes a mixed hcp-fcc phase due to a stacking fault progression. The reciprocal space map technique confirms the presence of both phases. Moreover, the precise determination of the Landé g-factor provides valuable insights into the structural properties. This careful study reveals the fundamental physics, but also provides important insight for potential applications of thin Co films with perpendicular magnetic anisotropy.

MA 28.8 Wed 16:45 EB 107

Thickness-dependent magneto-ionic effects in Fe thin films — •Ben Billinger[1], Arne Vereijken[2], Arno Ehresmann[2], Karin Leistner[1,3], and Markus Gössler[1] — [1]Institute of Chemistry, Chemnitz University of Technology — [2]Institute of Physics and CINSaT, University of Kassel — [3]Leibniz IFW Dresden

Magneto-ionics promises the reconfiguration of magnetic materials in a reversible and non-volatile manner.[1] Magnetic thin films, owing to their large surface-to-volume ratio, are particularly promising. In this study, we investigate the influence of film thickness on the magneto-ionic effect caused by the oxidation/reduction of sputtered iron thin films in aqueous electrolytes. Our iron films (10-100 nm) are covered by a native magnetite layer, which can be electrochemically reduced to ferromagnetic iron and re-oxidized reversibly, providing the basis for our magneto-ionic response.[2] We measure smaller coercivities in the reduced state, compared to the oxidized and pristine states, utilizing our in situ electrochemical Kerr microscopy setup.[2] The magnitude of the magneto-ionic effect, measured by relative changes in coercivity, can be enhanced to over 50% at small film thicknesses. For the smallest Fe thicknesses, the initial four-fold in-plane anisotropy of Fe levels out after magneto-ionic cycling, revealing a significantly increased coercivity compared to the pristine samples. We discuss our findings in terms of an increased surface roughness during reoxidation and highlight the importance of surface structure for future magneto-ionic devices. [1] M. Nichterwitz et al., APL Mater. 9, 030903 (2021), [2] J. Zehner et al., Adv. Electron. Mater. 6, 2000406 (2020)

MA 29: Spin-Dependent Phenomena in 2 D

Time: Wednesday 15:00–19:00 Location: EB 202

MA 29.1 Wed 15:00 EB 202

Is NiPS3 a good candidate to see the Berezinskii-Kosterlitz-Thouless transition? — •Yangjun Lee[1,2,3], Tae Yun Kim[2], and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, Korea

Magnetism in two-dimensional (2D) systems has been the subject of extensive study due to their distinct properties, which set them apart from three-dimensional (3D) systems. The Mermin-Wagner theorem asserts that continuous symmetry cannot be spontaneously broken in a 2D system in finite temperature. Nonetheless, the XY model, which exhibits continuous symmetry, demonstrates a phase transition at a non-zero temperature known as the Berezinskii-Kosterlitz-Thouless (BKT) transition. Recently, few-layer transition metal phosphorus trichalcogenides have garnered interest for their potential to exhibit intriguing 2D magnetic properties. Specifically, NiPS3 is regarded as an exemplar of XY model magnetism [1]. In this presentation, we will examine whether NiPS3 could be considered a promising candidate for observing the BKT transition [2, 3]. [1] Kim, K., Lim, S.Y., Lee, JU. et al. Nat. Commun. 10, 345 (2019). [2] T.Y. Kim and C.-H Park. Nano Lett. 21, 10114 (2021). [3] Y. Lee, T. Y. Kim, and C.-H. Park, unpublished.

MA 29.2 Wed 15:15 EB 202

An Effective Magnetic Model for FePS3 — •Minsu Ghim, Tae Yun Kim, and Cheol-Hwan Park — Department of Physics and Astronomy, Seoul National University, Seoul, Korea

Two-dimensional (2D) magnetism has drawn attention due to its properties distinct from those in three-dimensional magnetic systems. One of the most notable features is the Mermin-Wagner theorem, which states that with isotropic Heisenberg interactions, long-range magnetic order cannot exist at finite temperatures in a 2D system. Despite the Mermin-Wagner theorem, long-range magnetic order can still arise due to magnetic anisotropy. To understand 2D magnetism, extensive studies have been focused on establishing a model Hamiltonian for various materials. It is essential to develop an accurate magnetic energy model not only to characterize the ground state but also to explain phase transitions or low-energy excitations such as magnons. In this study, we focus on the magnetism of single-layer FePS3. We calculate the total energies and magnetic moments of various spin configurations. We conduct a quantitative analysis of the exchange interactions and discuss how FePS3 achieves its known ground state, the zigzag-type antiferromagnetism. [1, 2]

[1] T. Y. Kim, and C.-H. Park, Magnetic Anisotropy and Magnetic ordering of Transition-Metal Phosphorus Trisulfides, Nano Lett. 2021, 21, 23, 10114-10121 [2] M. Ghim, T. Y. Kim, C.-H. Park, unpublished

MA 29.3 Wed 15:30 EB 202

Topological magnon gap engineering in layered van der Waals ferromagnet CrI3 — •Verena Brehm[1], Pawel Sobieszczyk[2], Jostein Kløgetvedt[1], Richard F. L. Evans[3], Elton J. G. Santos[4], and Alireza Qaiumzadeh[1] — [1]NTNU Trondhem, Norway — [2]Polish Academy of Sciences Krakow, Poland — [3]University of York, United Kingdom — [4]University of Edinburgh, Untied Kingdom

We investigate the angular magnetic field dependence of the topological magnon gap at the K-points of the ferromagnetic van der Waals insulator CrI3, by examining two gap-opening terms: the Dzyaloshinski-Moriya and Kitaev interaction. Using stochastic atomistic spin dynamics simulations and linear spin wave theory, we compare the impact of the two spin interactions on the magnon spectra in a single layer. We observe three distinct magnetic field dependencies between these two topological magnon gap opening mechanisms that may distinguish the origin of the topological magnon gap. First, we demonstrate that the Kitaev-induced magnon gap is influenced by both the direction and amplitude of the applied magnetic field, while the DM-induced gap is solely affected by the magnetic field direction. Second, our findings reveal that the position of the Dirac cones within the Kitaev-induced magnon gap shifts dependent on the magnetic field direction, whereas they remain unaffected in the DM-induced gap scenario. Third, we find a direct-indirect magnon band-gap transition in the Kitaev model by varying the applied magnetic field.

MA 29.4 Wed 15:45 EB 202

Electrical engineering of topological magnetism in two-dimensional heterobilayers — •Nihad Abuawwad[1,2], Manuel dos Santos Dias[3], and Samir Lounis[1,2] — [1]Peter Grünberg Institute (PGI), FZJ, 52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany — [3]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

The emergence of topological magnetism in 2D van der Waals (vdW) materials has made 2D heterostructures vital for advanced information technology devices. Here, we show from first-principles calculations in combination with atomistic spin models that an external electric field modifies the vdW gap between $CrTe_2$ and (Rh, Ti)Te_2 layers and alters the underlying magnetic interactions. We demonstrate the all-electric switching of the topological nature of individual topological magnetic objects emerging in 2D vdW heterobilayers. The electric field enables switching between ferromagnetic skyrmions and meron pairs in the $CrTe_2$/$RhTe_2$ heterobilayer while it enhances the stability of frustrated antiferromagnetic merons in the $CrTe_2$/$TiTe_2$ heterobilayer. This discovery opens possibilities for energy-efficient information storage and transmission in spintronics [1,2,3].

–Work funded by the Palestinian-German Science Bridge (BMBF–01DH16027), and SPP 2244 (project LO 1659/7-1).

[1] arXiv:2311.01294, (2023). [2] Phys.Rev.B 108,094409 (2023). [3] J. Phys.: Condens. Matter 34 454001 (2022).

MA 29.5 Wed 16:00 EB 202

Magnetic Properties of Non-van der Waals 2D Materials — Tom Barnowsky[1,2], Mahdi Ghorbani-Asl[1], Thomas Heine[1,2], Stefano Curtarolo[3], Arkady V. Krasheninnikov[1,4], and •Rico Friedrich[1,2,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [2]TU Dresden — [3]Duke University, Durham, USA — [4]Aalto University, Aalto, Finland

While 2D materials are traditionally derived from bulk layered crystals bonded by weak van der Waals (vdW) forces, the recent surprising experimental realization of non-vdW 2D compounds obtained from non-layered transition metal oxides [1] foreshadows a new direction in 2D systems research.

As outlined by our recent data-driven investigations [2, 3], these materials exhibit unique magnetic properties owing to the magnetic cations at the surface of the sheets. Despite of several ferromagnetic candidates, even for the antiferromagnetic representatives, the surface spin polarizations are diverse ranging from moderate to large values modulated in addition by ferromagnetic and antiferromagnetic in-plane coupling. At the same time, chemical tuning by surface passivation provides a valuable handle to further control the magnetic properties of these novel 2D compounds [4] thus rendering them an attractive platform for fundamental and applied nanoscience.

[1] A. Puthirath Balan *et al.*, Nat. Nanotechnol. **13**, 602 (2018).
[2] R. Friedrich *et al.*, Nano Lett. **22**, 989 (2022).
[3] T. Barnowsky *et al.*, Adv. Electron. Mater. **9**, 2201112 (2023).
[4] T. Barnowsky *et al.*, submitted, arXiv:2310.07329 (2023).

MA 29.6 Wed 16:15 EB 202

Emergence of the Unconventional Magnetic Order in Twisted Double Bilayer CrI3 (Part 2) — •Ruoming Peng[1], King Cho Wong[1], Eric Anderson[2], Sarah Jenkins[3], Xiaodong Xu[2], Elton Santos[3], and Joerg Wrachtrup[1] — [1]3. Physikalisches Institut, University of Stuttgart, 70569 Stuttgart, Germany — [2]Department of Physics, University of Washington, Seattle, WA 98195, USA. — [3]Institute for Condensed Matter Physics and Complex Systems, School of Physics and Astronomy, The University of Edinburgh, Edinburgh, EH9 3FD, UK

The moiré superlattice in magnetic two-dimensional (2D) materials has revealed intriguing correlated and topological states. In the second part, we employ the scanning NV probe technique to investigate the antiferromagnetic domain of twisted double bilayer CrI3. Our study has shown that the magnetic competition in the moiré superlattice can contribute to the spontaneous periodic magnetic order in the twisted antiferromagnets. Notably, our observations include periodic antiferromagnetic texture with a period significantly larger than the moiré period and the emergence of the *skyrmion-like* lattices after a field cooldown process.

MA 29.7 Wed 16:30 EB 202

Emergence of the Unconventional Magnetic Order in Twisted Double Bilayer CrI3 (Part 1) — •King Cho Wong[1], Ruoming Peng[1], Joerg Wrachtrup[1], Eric Anderson[2], Xiaodong Xu[2], Elton Santo[3], and Sarah Jenkins[3] — [1]University of Stuttgart, Stuttgart, Germany — [2]University of Washington, USA — [3]University of Edinburgh, The United Kingdom

The twisted engineering of magnetic two-dimensional (2D) materials provides a controlled and versatile platform for exploring exotic correlated and topological states. Here, we employ the scanning NV probe technique to investigate the magnetic properties of twisted double bilayer CrI3. Our study has unveiled an unconventional ferromagnetic and antiferromagnetic behavior within the realm of twisted antiferromagnets. The manifestation of this magnetic order is underpinned by moiré-induced magnetic competition. Notably, our observations include a substantial domain wall width of approximately 100 nm and a consistent magnetization of 30 *b/nm^2 within small twisted-angle devices.

MA 29.8 Wed 16:45 EB 202

An all Phosphorene Lattice Nanometric Spin Valve — •Soumya Jyoti Ray — Indian Institute of Technology Patna

Phosphorene is a unique semiconducting two-dimensional platform for enabling spintronic devices integrated with phosphorene nanoelectronics. Here, we have designed an all phosphorene lattice lateral spin valve device, conceived via patterned magnetic substituted atoms of 3d-block elements at both ends of a phosphorene nanoribbon acting as ferromagnetic electrodes in the spin valve. Through First-principles based calculations, we have extensively studied the spin-dependent transport characteristics of the new spin valve structures. Systematic exploration of the magnetoresistance (MR) of the spin valve for various substitutional atoms and bias voltage resulted in a phase diagram offering a colossal MR for V and Cr-substitutional atoms. Such MR can be directly attributed to their specific electronic structure, which can be further tuned by a gate voltage, for electric field controlled spin valves. The spin-dependent transport characteristics here reveal new characteristics such as negative conductance oscillation and switching of the sign of MR due to change in the majority spin carrier type. Our study creates possibilities for design of nanometric spin valves, which could enable the integration of memory and logic for all phosphorene 2D processors.

15 min. break

MA 29.9 Wed 17:15 EB 202

Ferromagnetic Chromium Telluride Thin Films — Anna Tschesche, Pia Henning, and •Jasnamol Palakkal — Advanced Epitaxy, Institute of Materials Physics, Georg-August-University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Chromium-based chalcogenides belong to the few 2D materials known for their intrinsic ferromagnetism [1]. Chromium telluride thin films (i.e. Cr_2Te_3, CrTe, $CrTe_2$) come under this exceptional class having ferromagnetic ground states with different transition temperatures (T_C) and perpendicular magnetic anisotropy (PMA) [2-4].

Being relevant properties for applications such as magnetic random access memory (MRAM) devices, our aim is to find the Cr_xTe_y 2D material with the highest T_C and PMA. We successfully fabricated (0001)-oriented thin films of hexagonal Cr_xTe_y on Al_2O_3 (0001) substrates using our hybrid pulsed laser deposition (PLD) setup, that allows us to vary the Te-content via the temperature of a molecular beam source. All films show strong PMA at 5 K, with an easy axis of magnetization along out of plane direction and the T_C ranges from 155 K to 297 K. Further experiments were conducted and detailed results of the Cr_xTe_y-series will be presented.

[1] S. Yu et al., Science and Technology of Advanced Materials, 23 (2022) 140-160.

[2] Y. Wen et al., Nano Lett., 20 (2020) 3130-3139.

[3] X. Zhang et al., Nature Communications, 12 (2021) 2492.

[4] H. Zheng et al., Appl. Phys. Lett., 122 (2023) 023103.

MA 29.10 Wed 17:30 EB 202

Half-metallic transport and spin-polarized tunneling through the 2D ferromagnet Fe_4GeTe_2 — •Anita Halder[1,2], Declan Nell[1], Antik Sihi[1], Stefano Sanvito[1], and Andrea Droghetti[1,3] — [1]Trinity College Dublin, Dublin, Ireland — [2]SRM University-AP, Amravati, India — [3]CNR-SPIN, at G. d'Annunzio University, Chieti, Italy

The discovery of ferromagnetic 2D van der Waals (vdW) materials, Fe_nGeTe_2 (FGT) (n=3-5), has attracted attention for spintronics applications due to their high Curie temperature. We theoretically study the spin-dependent transport properties of Fe_4GeTe_2 (FGT4) using density functional theory and Non-equilibrium Green's Functions. We show that the conductance perpendicular to the 2D vdW layer is half-metallic, i.e. entirely spin-polarized (SP). This high SP remains robust transitioning from bulk to a single layer. Additionally, a large SP current is observed when the system is driven out of equilibrium up to a significant bias. This spin-dependent transport is largely unaffected in the presence of spin-orbit coupling and electron-electron correlation effects. Leveraging the spin-filtering capability of monolayer FGT4 presents an opportunity for designing a magnetic tunnel junction (MTJ) using 2D vdW materials, offering high tunnel magnetoresistance (TMR). An MTJ device exploiting the vdW gap as an insulating barrier between two FGT4 layers achieves a TMR of almost 500%. These findings may inspire further theoretical and experimental studies for designing more realistic spintronic devices, replacing conventional FM with 2D vdW materials.

MA 29.11 Wed 17:45 EB 202

Understanding of Co and Ni doping in 2D Fe_5GeTe_2 magnets via first principles theory — •Biplab Sanyal[1], Soheil Ershadrad[1], Sukanya Ghosh[1,2], and Masoumeh Davoudiniya[1] — [1]Department of Physics & Astronomy, Uppsala University, Box.516, 75120 Uppsala, Sweden — [2]VIT Bhopal, India

In recent times, the family of 2D Fe_nGeTe_2 (n=3-5) magnets with van der Waals (vdW) stacked layers has attracted enormous attention due to high Curie temperatures and the potential of use in spintronic applications. The possibility of tunability in structural, electronic and magnetic properties has been instrumental in achieving novel properties in these 2D magnets and their heterostructures. Furthermore, recent experimental studies have revealed unusual magnetic phenomena by doping with Ni or Co in Fe_5GeTe_2 in particular, which calls for detailed quantitative analysis. In this presentation, with the aid of first principles theory, a systematic evolution of magnetic exchange interactions and Curie temperatures with Ni doping will be demonstrated. The microscopic mechanisms will be presented as an interplay between specific magnetic exchange interactions, magnetic anisotropy and Dzyaloshinskii-Moriya interactions. Moreover, the role of dynamical correlation will be highlighted via the study with dynamical mean field theory. The case of Co doping will be highlighted to explain the magnetic anisotropy change due to doping via the analysis of atom and orbital resolved magnetic anisotropy energies. For both the cases with Co and Ni doping, our results are in good agreement with the experimental observations.

MA 29.12 Wed 18:00 EB 202

Evolution of van der Waals gap and exchange bias in $Fe_3GeTe_2/MnPS_3$ vdW heterostructure — Aravind Puthirath Balan[1], •Aditya Kumar[1], Patrick Reiser[2], Joseph Vimal Vas[3], Thibaud Denneulin[3], Andras Kovacs[3], Patrick Maletinsky[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudinger Weg 7, 55128 Mainz, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany

The inherent layered structure of Van der Waals (vdW) materials allows the fabrication of heterostructures with perfect interfaces and the study of interface-related phenomena such as Exchange bias (EB) [1]. This study presents a comprehensive analysis of EB in the Fe_3GeTe_2 (FM) and $MnPS_3$ (AFM) vdW heterostructure, revealing insights into its origin and unique evolving nature. A large EB of 170 mT was observed at 5K in this system due to pinning from anomalous ferromagnetic ordering that emerges in $MnPS_3$ at low temperatures. The evolving nature of EB is due to thermal cycling-induced modification of the interface registry, accompanied by vdW gap modification, as confirmed by STEM measurements. This work offers new insights into the nature of interfaces between vdW materials and the potential method for tuning EB and the vdW gap.

[1] Balan et al. arXiv preprint arXiv:2303.13167 (2023)

MA 29.13 Wed 18:15 EB 202

Hyperfine interactions in open-shell planar sp^2-carbon nanostructures — Sanghita Sengupta[1], Thomas Frederiksen[1,2], and •Géza Giedke[1,2] — [1]Donostia International Physics Center (DIPC), E-20018, Donostia-San Sebastián, Spai — [2]IKERBASQUE, Basque Foundation for Science, E-48013, Bilbao, Spain

We investigate hyperfine interaction (HFI) using density-functional theory for several open-shell planar sp^2-carbon nanostructures displaying π magnetism such as $[n]$triangulenes and graphene nanoribbons. Our results indicate that HFI can reach 100 MHz and that isotropic Fermi contact and anisotropic dipolar terms contribute in comparable strength, rendering the HFI markedly anisotropic. Using these results we obtain empirical models using generic sp^2-HFI fit parameters that connect the HFI to the π-spin polarizations at carbon sites only. These models successfully describe the Fermi contact and dipolar contributions for 13 C and 1 H nuclei and allow to obtain hyperfine tensors for large systems where existing methodology is not suitable or computationally too expensive. Implications of the obtained HFI for electron-spin decoherence, dynamical nuclear polarization, and for coherent nuclear dynamics are discussed.

MA 29.14 Wed 18:30 EB 202

Magnetic ordering in weakly coupled van der Waals systems — •Karel Carva and Krishna K. Pokhrel — Charles University, Faculty of Mathematics and Physics, DCMP, Ke Karlovu 5, 121 16 Prague 2, Czech Republic

Magnetic van der Waals materials exhibit promising potential for high-tech magnetic applications in nanostructures [1]. Their weak interlayer coupling leads to magnetic behavior different from the more explored cases of isotropic bulk-like exchange or the ideal 2D (monolayer) limit [2]. Here we examine general features of finite temperature magnetic order in this regime by atomistic spin dynamics methods. The method is applied to a particularly interesting system from this class, VI_3. Its anisotropy was reproduced by first-principles calculations only if lattice distortions present at its low temperature phases were taken into account [3]. The calculations also revealed an exceptionally large orbital momentum on V atoms; these findings are compared to recent measurements based on the x-ray magnetic circular dichroism [4]. Employing calculated exchange interactions we study how is the Curie temperature affected by interlayer coupling in this system.

[1] K. Burch, et al., Nature 63 (2018) 47
[2] V. Y. Irkhin, A. A. Katanin, and M. I. Katsnelson, Phys. Rev. B 60 (1999) 1082
[3] L. M. Sandratskii and K. Carva, Phys. Rev. B 103 (2021) 214451
[4] D. Hovančík et al., Nano Lett. 23 (2023) 1175

MA 29.15 Wed 18:45 EB 202

Emergent altermagnetism: magnetically induced anomalous Hall conductivity — •Toshihiro Sato[1], Sonia Haddad[2], Ion Cosma Fulga[1], Fakher F. Assaad[3,4], and Jeroen van den Brink[1,4,5] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Laboratoire de Physique de la Matière Condensée, Faculté des Sciences de Tunis, Université Tunis El Manar, Tunisia — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany — [4]Würzburg-Dresden Cluster of Excellence ct.qmat, Germany — [5]Institut für Theoretische Physik, Technische Universität Dresden, Germany

We introduce a novel model that demonstrates the emergence of altermagnetism driven by electron interactions. This model is grounded in a spin-full modified Haldane framework, where electron interactions play a crucial role. Employing quantum Monte Carlo simulations, we successfully demonstrate the emergence of an altermagentic phase. This phase exhibits spontaneously time-reversal symmetry-broken antiferromagnetic order and is characterized by spin-split bands without a net magnetic moment. Moreover, a significant observation is the simultaneous emergence of an anomalous quantum Hall order alongside this antiferromagnetic order. The concurrent appearance of both orders results in a measurable, finite anomalous Hall conductivity.

MA 30: Skyrmions II

Time: Wednesday 15:00–18:30 Location: EB 301

Invited Talk MA 30.1 Wed 15:00 EB 301

Discovery of Hopfion rings in a cubic chiral magnet — •Nikolai Kiselev — Institute for Advanced Simulation and Peter Grünberg Institute, Forschungsyentrum Jülich, 52425 Jülich Germany

Magnetic skyrmions are two-dimensional topological solitons resembling vortex-like strings in the magnetization field that penetrate an entire sample. In contrast, hopfions are topological solitons localized in all three dimensions and manifest as closed loops of skyrmion strings, often taking the shape of a ring. While hopfions were theoretically predicted in specific magnetic systems [1], their direct observation has been elusive since, in most magnetic systems, isolated hopfions are unstable. Our discovery reveals that in crystals of cubic chiral magnets, hopfions become stable when linked with skyrmion strings [2]. This talk presents the direct observation of such hopfions in B20-type FeGe plates using transmission electron microscopy. Various aspects of hopfion rings will be discussed, including a reliable protocol for hopfion ring nucleation, a quantitative comparison between theory and experiment, a homotopy group analysis of these topological states, and an examination of zero modes of hopfion rings moving along skyrmion strings.

[1] Rybakov, F. N. et al. APL Mater. **10**, 111113 (2022).
[2] Zheng, F. et al., Nature **623**, 718 (2023).

MA 30.2 Wed 15:30 EB 301

Probing Chirality and Topology in Ferrimagnetic Multilayer Systems — •Tamer Karaman[1], Kai Litzius[1], Daniel Metternich[2], Timo Schmidt[1], Aladin Ulrich[1], Andrada-Oana Mandru[3], Reshma Peremadathil Pradeep[3], Hans Josef Hug[3], Manfred Albrecht[1], and Felix Büttner[1,2] — [1]University of Augsburg, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]EMPA, Dübendorf, Switzerland

Chiral rare-earth transition metal ferrimagnets show promise for skyrmion-based spintronics applications due to their unique material properties, such as Néel-type bulk DMI, tunable anisotropy, and negligible stray fields [1, 2]. This class of ferrimagnets combines features from both ferromagnets and antiferromagnets [3]. Using Fresnel Lorentz Transmission Electron Microscopy, we investigate thick ferrimagnetic Dy/Co multilayer films. We observe the coexistence of skyrmions and topologically trivial bubbles under varying tilt and magnetic fields, revealing a delicate balance of micromagnetic interactions. Additionally, a stable worm domain pattern emerges, acting as a guiding pathway for normal domains. This study underscores the importance of local real-space probes in understanding chiral ferrimagnets, paving the way for further exploration and exploitation of these materials.

1. Kim, S. K. et al. Nat. Mater. 21, 24 (2022). 2. Fert, A., et al Nat. Rev. Mater. 2, 17031 (2017). 3. Caretta, L. et al. Nat. Nanotechnol. 13, 1154 (2018).

MA 30.3 Wed 15:45 EB 301

The dynamics of Skyrmion shrinking — •Frederik Austrup[1], Wolfgang Häusler[2], Michael Lau[1], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]Institute of Physics, University of Augsburg

It is generally accepted that Skyrmions shrink in size before they decay when unstable. We present numerical studies to identify values for the external parameters, including the applied magnetic field and the Dzyaloshinskii-Moriya interaction strength, stabilizing Skyrmions in two-dimensional ferromagnets. Further, we follow their time evolution in the unstable cases, for different lattice constants and in the presence of Gilbert damping. Contrary to the commonly expected simply exponentially decreasing size we find a more complicated time dependence. The time evolution of the Skyrmion radius ρ_0 can be divided into three phases: $\rho_0(t)$ starts decreasing quadratically in time before it continues according to an exponential law over a certain period of time. However, before reaching a time t_c, a behavior consistent with a square root decay, $\sim (t-t_c)^{1/2}$, is found. Analytically, we derive a differential equation for $\rho_0(t)$ from the Landau-Lifshitz-Gilbert equation for the time-dependent topological charge density, utilizing a Skyrmion profile of triangular shape. Solving this equation, we find indeed a shrinking behaviour nicely following the observed exponential law that crosses over into a square root decay pattern. The time t_c is found to depend on Zeeman-field and on exchange field strengths, and on the initial Skyrmion size.

MA 30.4 Wed 16:00 EB 301

Chemical potential of magnetic skyrmion quasiparticles in heavy metal/iron bilayers — •Balázs Nagyfalusi[1], László Udvardi[1], László Szunyogh[1,2], and Levente Rózsa[3,1] — [1]Budapest University of Technology and Economics, Budapest Hungary — [2]HUN-REN-BME Condensed Matter Research Group, Budapest, Hungary — [3]HUN-REN Wigner Research Center for Physics, Budapest, Hungary

We performed metadynamics Monte Carlo simulations to obtain the free energy as a function of the topological charge in the skyrmion-hosting magnetic model systems ($Pt_{0.95}Ir_{0.05}$)/Fe/Pd(111) and Pd/Fe/Ir(111), using a spin model containing parameters based on ab initio calculations. Using the topological charge as collective variable, this method allows for evaluating the temperature dependence of the number of skyrmionic quasiparticles. In addition, from the free-energy cost of increasing and decreasing the topological charge of the system we determined chemical potentials as a function of the temperature. At lower temperature, the chemical potential for creating skyrmions and antiskyrmions from the topologically trivial state is different. This splitting of the chemical potential is particularly pronounced for large external magnetic fields when the system is in a field-polarized phase. We observed a change in the shape of the free-energy curves when skyrmion-skyrmion interactions become more pronounced.

MA 30.5 Wed 16:15 EB 301

Stability of nonlocal magnetic solitons in an all-magnetic van der Waals heterostructure — •Moritz A. Goerzen[1], Dongzhe Li[2], Soumyajyoti Haldar[1], Tim Drevelow[1], and Stefan Heinze[1,3] — [1]ITAP, University of Kiel, Germany — [2]CEMES, Université de Toulouse, CNRS, France — [3]KiNSIS, University of Kiel, Germany

Stabilizing and controlling multiple topological spin states in atomically thin van der Waals (vdW) materials gained tremendous attention due to high tunability, enhanced functionality, and miniaturization. Here, using first-principles and atomistic spin simulations [1], we investigate the existence of multiple topological spin textures in an all-magnetic vdW heterostructure $Fe_3GeTe_2/Cr_2Ge_2Te_6$ (FGT/CGT). These states obey opposite rotational senses at the two sides of the FGT/CGT interface, which is in agreement with recent experimental measurements [2]. Magnetic skyrmions at the FGT layer and bimerons at the CGT layer persist in the heterostructure with zero magnetic field while the later undergo bimeron-skyrmion transformation if a field is applied. Furthermore, we show evidence of nonlocal spatial expanse, which makes them subject to finite-size effects. We analyze how this affects the stability of states in confined materials.

[1] Li *et al.*, Phys. Nano Lett. **22**, 7706-7713 (2022)
[2] Wu *et al.*, Adv. Mater. **34**, 2110583 (2022)

MA 30.6 Wed 16:30 EB 301

Laser-induced real-space topology control of spin wave resonances — •Tim Titze[1], Sabri Koraltan[2], Timo Schmidt[3], Marcel Möller[4], Florian Bruckner[2], Claas Abert[2], Dieter Suess[2], Claus Ropers[4], Daniel Steil[1], Manfred Albrecht[3], and Stefan Mathias[1] — [1]University of Göttingen, Germany — [2]University of Vienna, Austria — [3]University of Augsburg, Germany — [4]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany

Materials exhibiting magnetic spin textures promise advanced magnetic control via the generation of laser-induced ultrafast and non-equilibrium spin dynamics. We investigate ferrimagnetic $[Fe(0.35\,nm)/Gd(0.40\,nm)]_{160}$ multilayers, which host a rich diversity of magnetic spin textures including stripe domains, a dense bubble/skyrmion (B/SK) lattice, and a single domain state [1, 2]. Using fs Kerr spectroscopy, we can unambiguously identify the different magnetic spin textures, as we observe distinct coherent spin wave dynamics in response to weak laser excitation. Strong laser excitation allows us to achieve versatile control of the coherent spin dynamics via non-equilibrium and ultrafast transformation of magnetic spin textures by both creating and annihilating B/SKs. We further corroborate these findings by micromagnetic simulations and Lorentz transmission electron microscopy with in-situ optical excitation [3].

[1] S. A. Montoya *et al.*, Phys. Rev. B **95**, 2024415 (2017)
[2] M. Heigl *et al.*, Nat. Commun. **12**, 261 (2021)
[3] T. Titze *et al.*, arXiv preprint arXiv:2309.12956 (2023)

15 min. break

MA 30.7 Wed 17:00 EB 301

Reversible topological transformation of skymions and trivial bubbles — •Timo Schmidt[1], Sabri Koraltan[2], and Manfred Albrecht[1] — [1]Universität Augsburg, Augsburg, Germany — [2]Universität Wien, Wien, Austria

Magnetic skyrmions and type-2-bubbles represent topologically distinct spin textures that have garnered significant attention in the field of condensed matter physics due to their unique properties and potential applications in information storage and processing. While these objects can be stabilized in a wide variety of materials by different mechanisms, this work focusses on dipolar stabilized spin textures in amorphous Fe/Gd-multilayer thin films. These systems are sputter-deposited on SiN-membranes.

Using Lorentz transmission electron microscopy (LTEM) round spin textures can be imaged as they nucleate from the stripe domain state by applying a magnetic field in out-of-plane direction. We observe distinct locations on the membrane where certain types of spin objects are stabilized predominantly and attribute this to the wrinkling of the membrane. Due to this wrinkling, which originates in the sample manufacturing process, there are intrinsically tilted regions on the membrane, resulting in an effective in-plane field component. Tilting of the whole sample in the range of up to 18° shows, that by changing the contribution of the ip-field, topologically trivial type-2-bubbles can be transformed into topologically protected skyrmions and vice versa.

MA 30.8 Wed 17:15 EB 301

Skyrmion motion in magnetic anisotropy gradients: Acceleration caused by deformation — •Ismael Ribeiro de Assis, Ingrid Mertig, and Börge Göbel — Institut für Physik, Martin-Luther-Universität, Halle (Saale), Germany

Magnetic skyrmions are nano-sized topologically non-trivial spin textures that can be moved by external stimuli such as spin currents and internal stimuli such as spatial gradients of a material parameter. Since the total energy of a skyrmion depends linearly on most of these parameters, like the perpendicular magnetic anisotropy, the exchange constant, or the Dzyaloshinskii-Moriya interaction strength, a skyrmion will move uniformly in a weak parameter gradient. In this paper, we show that the linear behavior changes once the gradients are strong enough so that the magnetic profile of a skyrmion is significantly altered throughout the propagation. In that case, the skyrmion experiences acceleration and moves along a curved trajectory. Furthermore, we show that when spin-orbit torques and material parameter gradients trigger a skyrmion motion, it can move on a straight path along the current or gradient direction. We discuss the significance of suppressing the skyrmion Hall effect for spintronic and neuromorphic applications of skyrmions. Lastly, we extend our discussion and compare it to a gradient generated by the Dzyaloshinskii*Moriya interaction.

MA 30.9 Wed 17:30 EB 301

Unveiling the origin of square skyrmion lattice in $GdRu_2Si_2$ and effect of uniaxial pressure: Insights from theory — •Rohit Pathak[1], Sagar Sarkar[1], Olle Eriksson[1,2], and Vladislav Borisov[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden — [2]Wallenberg Initiative Materials Science for Sustainability, Uppsala University, 75121 Uppsala, Sweden

The miniaturization of skyrmion holds promise for high-density memory technology applications [1]. This study delves into the magnetic properties of the $GdRu_2Si_2$ alloy, experimentally known to host nanometer-sized square skyrmion lattices [2]. Employing the first-principle density functional theory (DFT) [3] and atomistic spin dynamics simulations [4], we aim to understand the microscopic origins of the formation of the skyrmion lattice. Our investigation reveals that the interplay between frustration in exchange interactions and uniaxial anisotropy plays an essential role here. Additionally, we intend to explore the impact of uniaxial pressure on exchange interactions and magnetic anisotropy, thereby examining alterations to the magnetic phase diagram. [1] Göbel, B. et al., Phys. Rep. 895, 1*28 (2021). [2]

Khanh, N. D. et al., Nat. Nanotechnol. 15, 444*449 (2020) [3] Wills, J. M. et al. Full-Potential Electronic Structure Method (Springer, 2010) [4] Eriksson et al. Atomistic Spin Dynamics: Foundations and Applications (Oxford University Press, 2017). This work was financially supported by the Knut and Alice Wallenberg (KAW), Göran Gustafsson, and Carl Tryggers Foundations.

MA 30.10 Wed 17:45 EB 301

Skyrmions and Hopfions: topological chirality emerging from dipole-dipole interactions — •Svitlana Kondovych[1] and Igor Luk'yanchuk[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [2]Laboratory of Condensed Matter Physics, University of Picardie, 80039 Amiens, France

Confined ferroics display non-uniform vector field texturing, driven by the interplay of dipole-dipole interactions, elastic strains, anisotropic energy, and confinement effects. Topologically non-trivial, chirality-endowed structures like Bloch domain walls, merons, skyrmions, and Hopfions attract attention for their fundamental importance and diverse applications. In magnetic [1-3] and ferroelectric [4,5] materials, chirality spontaneously emerges to minimize stray fields, even without the local, Dzyaloshinskii-Moriya-like antisymmetric exchange.

We present a theoretical framework to elucidate the role of dipole-dipole interactions in formation of chiral topological states in nanosized ferroic structures. Through various examples, we illustrate non-uniform confined vector fields, highlighting the possibility to tailor and manipulate their swirling and handedness.

S.K. acknowledges the support from the Alexander von Humboldt Foundation.

[1] E. Berganza, et al., Sci. Rep. 12, 3426 (2022).
[2] F. Büttner, et al., Sci. Rep. 8, 1-12 (2018).
[3] J. Schöpf, et al. Nano Letters 23.8, 3532-3539 (2023).
[4] I. Lukyanchuk, et al., Nat. Commun. 11, 2433 (2020).
[5] Y. Tikhonov, et al., Sci. Rep. 10, 8657 (2020).

MA 30.11 Wed 18:00 EB 301

Ab-initio study of the topological Hall effect in Pd/Fe/Ir(111) — •Adamantia Kosma[1], Philipp Rüssmann[1,2], Stefan Blügel[1], and Phivos Mavropoulos[3] — [1]Forschungszentrum Jülich — [2]University of Würzburg — [3]National and Kapodistrian University of Athens

This study comprises an ab-initio computational investigation of the topological Hall effect (THE) arising from magnetic skyrmions in thin film Pd/Fe/Ir(111)[1]. The research is motivated by the significance of electrically detecting magnetic skyrmions for spintronic applications. To achieve the formation of stable magnetic skyrmions in this system, we employ non-collinear spin-density-functional theory within the Korringa-Kohn-Rostoker (KKR) Green function method. The multiple scattering problem is solved using the full-potential relativistic KKR method [2], and subsequently, the spin-transport calculations are carried out using the Boltzmann formalism [3] to find the resistivity and the topological Hall angle. We investigate the influence of the skyrmion size on the Hall angle and explore the impact of additional electron scattering, modeled as random disorder broadening, on the THE. Our findings indicate a significant correlation between the THE and the degree of disorder in a sample.

We thank the ML4Q (EXC 2004/1 - 390534769) for funding.

[1] N. Romming *et al.*, Science **341** 6146 (2013).
[2] JuDFTteam/JuKKR (2022). doi: 10.5281/zenodo.7284738
[3] A. Kosma *et al.*, Phys. Rev. B **102** 144424 (2020).

MA 30.12 Wed 18:15 EB 301

Classification of real- and reciprocal space topology in skyrmion crystals — •Pascal Prass[1], Fabian R. Lux[2], Duco van Straten[3], and Yuriy Mokrousov[1,4] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Department of Physics, Yeshiva University, New York, NY 10016, USA — [3]Institute of Mathematics, Johannes Gutenberg University Mainz, Germany — [4]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany

As the length scale of a two-dimensional skyrmion crystal approaches the lattice constant of its host material, topological gaps may form in the associated electronic system. However, the smooth texture approximation for the usual geometric approach of emergent magnetic fields is no longer satisfied. Instead, we adopt a fully algebraic view to describe a class of multi-q textures [1], including skyrmion crystals, and apply noncommutative K-theory to compute all admissible Chern numbers. As a central application, we tune the texture parameters, creating discontinuous jumps in the real-space winding number [2,3] for which we observe the relation with Chern numbers of the electronic spectrum. In conclusion, our work gives an exhaustive classification of the electronic state topology in skyrmion crystals and can form the basis for a sophisticated design of topological electronic states in more general magnetic multi-q systems. [1] Lux et al. Phys. Rev. Res. *in press* (2023/24). [2] Hayami et al. Nat. Commun. 12, 6927 (2021). [3] Shimizu et al. Phys. Rev. B 105, 224405 (2022).

MA 31: Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)

Time: Wednesday 15:00–18:00 Location: EB 407

MA 31.1 Wed 15:00 EB 407

Real-time imaging of nonequilibrium domain evolution into a multiferroic phase — •Jan Gerrit Horstmann[1], Yannik Zemp[1], Ehsan Hassanpour Yesaghi[1], Thomas Lottermoser[1], Mads C. Weber[2], and Manfred Fiebig[1] — [1]Dept. of Materials, ETH Zurich, Switzerland — [2]Institut des Molécules et Matériaux du Mans, Le Mans Université, France

We investigate the dynamics of magnetic domain formation across spin-reorientation transitions in multiferroic $Dy_{0.7}Tb_{0.3}FeO_3$. Combining Faraday imaging at kHz frame rates with fast optical excitation we find that thermal quenches of the system can be harnessed to imprint the characteristic bubble domain pattern of the weak ferromagnetic order at elevated temperatures onto the low-temperature multiferroic phase. We identify the quenching rate across the different spin reorientation transitions as the decisive parameter governing the domain memory and the formation of metastable domain states forbidden in thermal equilibrium. Our results highlight the potential of optical stimuli for the switching and control of multiferroic domain structures, enabling the creation of new functional states via nonequilibrium pathways.

MA 31.2 Wed 15:15 EB 407

Asymmetry of the magnetic-field-driven phase transition in h-ErMnO$_3$ — •Lea Forster[1], Ipek Efe[1], Morgan Trassin[1], Manfred Fiebig[1], Thomas Lottermoser[1], and Mads C. Weber[2] — [1]Department of Materials, ETH Zurich, Switzerland — [2]IMMM UMR 6283, University Le Mans, France

We report on the asymmetry of the magnetic-field-induced phase transition of the Mn^{3+} order in hexagonal $ErMnO_3$ under magnetic field application along the six-fold axis. Below the Néel temperature, we observe that with increasing magnetic field the Mn^{3+} and Er^{3+} appear to reorder simultaneously. However, with decreasing magnetic field, the reverse phase transition of the Mn^{3+} shows an intermediate stage where the spins are partially in the zero-field and partially in the applied-field state, while the Er^{3+} reverses almost instantaneously to its zero-field state. This asymmetry of the forward and reverse transition in the Mn^{3+} order becomes more and more pronounced at lower temperatures. We gain access to both the Mn^{3+} and Er^{3+} sublattices using optical second-harmonic generation and SQUID magnetometry. Our investigation of this asymmetric magnetic field-induced phase transition further underlines the complex coupling mechanisms of the Mn^{3+} order to the rare-earth orders in hexagonal manganites.

MA 31.3 Wed 15:30 EB 407

Magnetoelectric Effects in 2D Magnets: A Multiscale Approach Applied to Topological Solitons in CrI$_3$ — •Alexander Edström[1], Paolo Barone[2], Silvia Picozzi[3], and Massimiliano Stengel[4,5] — [1]Department of Applied Physics, KTH Royal Institute of Technology, 10691 Stockholm, Sweden — [2]CNR-SPIN, Area della Ricerca di Tor Vergata, Via del Fosso del Cavaliere 100, I-00133 Rome, Italy — [3]CNR-SPIN, c/o Università degli Studi 'G. D'Annunzio', 66100, Chieti, Italy — [4]ICMAB-CSIC, Campus UAB, 08193 Bellaterra, Spain — [5]ICREA , 08010 Barcelona, Spain

Topological defects, such as domain walls or Skyrmions, are expected to carry an electrical polarization, opening for the possibility to stabilize, control and detect them with electric fields, even in collinear ferromagnets like CrI_3. Here, we present a multiscale approach, combining atomistic and continuum magnetoelectric models, to accurately describe magnetoelectric coupling at different length scales, with all parameters extracted from first principles. The models are validated for spin spirals, revealing a sizeable magnetoelectric polarization. We describe the relation of the magnetoelectric parameters to electric field-induced Dzyaloshinskii-Moriya interactions. The models are then used to calculate the electric polarization and net dipole moments of magnetic domain walls (DWs) and Skyrmions, revealing e.g. that Skyrmions carry an out-of-plane electric dipole moment, while that of anti-Skyrmions lies in the plane. Finally, we discuss the possibility to stabilize these magnetic textures, none of which are otherwise energetically stable in the monolayer limit of CrI_3, using electric fields.

MA 31.4 Wed 15:45 EB 407

Electric field-driven dynamics of meron domain walls in spin spiral multiferroics — •Luca Maranzana[1,2] and Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genoa, Italy — [2]University of Genoa, Genoa, Italy

Spin spiral multiferroics exhibit strong coupling between magnetic and ferroelectric orders, allowing cross-control. Since their discovery by Kimura et al. in 2003, these materials have attracted great interest galvanized by the prospect of new high-efficiency information storage devices, where the magnetic bits are switched through an external electric field. Nevertheless, the electric field-driven dynamics of domain walls in spin spiral multiferroics (i.e. the mechanism underlying this switching) is still poorly understood. Here, we address this problem for meron domain walls, which arise at low anisotropy and consist of a periodic chain of merons (half-skyrmions). The topological charge lies at the heart of the dynamics and can be controlled by modifying the meron configuration or applying an external magnetic field. Domain walls with zero total topological charge present a low-field dynamics reminiscent of a massive particle in one dimension. In contrast, those with non-zero total topological charge evince a peculiar nonlocal dynamics where all the spins in the system rotate and the mobility is drastically reduced.

MA 31.5 Wed 16:00 EB 407

Antimagnetoelectricry in multiferroic $BiCoO_3$ from first-principles — •Bogdan Guster[1], Maxime Braun[1,2], Houria Kabbour[2], and Eric Bousquet[1] — [1]Physique Théorique des Matériaux, QMAT, CESAM, Université de Liège, B-4000 Sart-Tilman, Belgium — [2]Univ. Lille, CNRS, Centrale Lille, ENSCL, Univ. Artois, UMR 8181-UCCS-Unité de Catalyse et Chimie du Solide, F-59000 Lille, France

The lack of magnetoelectric response in a multiferroics is prompted by the magnetic space group symmetry. This is the case of $BiCoO_3$ where the C-AFM ground state prohibits the promotion of a magnetoelectric coupling. However, at the microscopic level, the local magnetoelectric coupling could exhibit non-zero responses for both spin and orbital components. Here we show from first-principles calculations that the amplitude of dynamical magnetic charges arising from both spin- and orbital-lattice coupling in the C-AFM phase of $BiCoO_3$ are large when compared to the paradigmatic Cr_2O_3. While globally the response is zero, we resolute that the pseudo-tensorial character of the dynamical magnetic charges manifests an alternating sign for atoms yet on the same Wyckoff position. Consequently, unlocking the C-AFM phase, one could potentially allow for a large magnetoelectric response. To prove this, we calculate the full magnetoelectric response in the ferromagnetic phase of $BiCoO_3$ and we find a colossal response of 1000 ps/m, among the largest reponses found so far in a single-crystal. We will discuss several strategies on how this large response could be released in some specific conditions and why the response is large.

MA 31.6 Wed 16:15 EB 407

Electric field induced reversal of spin alignment in graphone/hexagonal boron nitride on Ni(111) — Jaime Oliveira da Silva and •Fernando Nogueira — CFisUC, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal

Spintronic applications require a precise and efficient way of manipulating the material's magnetisation. This work demonstrates that it is possible to revert the surface magnetisation of a graphene sheet covered in half by hydrogen by applying an external electric field. To demonstrate this possibility, we study a prototypical material where this effect occurs: a 2D layer material formed by a Ni(111) substrate, an hBN monolayer and a graphone sheet. Screening of the Coulomb interactions between the ferromagnetic surface and the graphone layer plays a key role int the magnetisation reversal, enabling graphone to partially recover its isolated magnetisation value. The screening is due to the forming of an ionic bond between the N and B atoms in the hBN sheet. As the proposed material has a flat band at the Fermi level, our work also provides prospects for investigating flat-band instabilities.

15 min. break

MA 31.7 Wed 16:45 EB 407

Thermal conductivity in multiferroic CaBaCo4O7 — •Reza Firouzmandi[1], Matthias Gillig[1], Yusuke Tokunaga[2], Yasujiro Taguchi[2], Yoshinori Tokura[2], Christian Hess[3], Vilmos Kocsis[1], and Bernd Büchner[1] — [1]IFW-Dresden, Dresden, Germany — [2]RIKEN-CEMS, Wako, Japan — [3]University of Wuppertal, Wuppertal, Germany

The coupling between the electronic and magnetic degrees of freedoms can lead to exotic transport phenomena in multiferroic materials. Particularly the propagation of charge neutral heat carriers can reveal interesting features in the thermal transport properties. Here, we report the thermal conductivity measurements in multiferroic CaBaCo4O7 which is built up by alternating Kagome and triangular layers of edge sharing CoO4 tetrahedra in mixed valence state. We find anomalies related to the magnetic ordering as well as huge anisotropy in thermal conductivity. Field dependence of the thermal conductivity resembles to that of the ferroelectric polarization. We attribute the anisotropy to the strong phonon scattering on the orthorhombic twinning.

MA 31.8 Wed 17:00 EB 407

Non-trivial Spin Structures And Multiferroic Properties Of The DMI-Compound Ba2CuGe2O7 — •Korbinian Fellner[1], Sebastian Mühlbauer[1], Peter Wild[1], Michal Dembski-Villalta[1], Tommy Kotte[2], Markus Garst[3], Alexandra Turrini[4], and Bertrand Roessli[4] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe. Germany — [4]Paul Scherrer Institut (PSI), Villigen, Switzerland

Incommensurate spiral magnets have raised tremendous interest in recent years, mainly motivated by their wealth of spin structures, such as skyrmions. A second field of interest is multiferroicity: Helical spin structures are in general ferroelectric, enabling the coupling of the electric and magnetic properties. Ba2CuGe2O7, featuring a quasi-2D structure with Dzyaloshinskii-Moriya interactions (DMI), is a material that is interesting in both of these regards and combines them with a third one: a variety of unconventional magnetic phase transitions. Neutron diffraction is used for an examination of the distribution of critical fluctuations in reciprocal space, associated with the paramagnetic to helimagnetic transition of Ba2CuGe2O7. It's reduced dimensionality prompts a transition from incommensurate antiferromagnetic fluctuations to 2D antiferromagnetic Heisenberg fluctuations, showcasing a varied array of magnetic phase transitions in spiral textures. Recently, a new phase with a vortex-antivortex magnetic structure has been theoretically described and experimentally confirmed.

MA 31.9 Wed 17:15 EB 407

Atomic-scale visualization of multiferroicity in monolayer NiI_2 — Mohammad Amini[1], •Adolfo Fumega[1], Hector Gonzalez-Herrero[1,2,3], Viliam Vano[1,4], Shawulienu Kezilebieke[5], Jose Lado[1], and Peter Liljeroth[1] — [1]Department of Applied Physics, Aalto University, FI-00076 Aalto, Finland — [2]Departamento de Fisica de la Materia Condensada, Universidad Autonoma de Madrid, E-28049 Madrid, Spain — [3]Condensed Matter Physics Center (IFIMAC), Universidad Autonoma de Madrid, E-28049 Madrid, Spain — [4]Joseph Henry Laboratories and Department of Physics, Princeton University, Princeton, NJ 08544, USA — [5]Department of Physics, Department of Chemistry and Nanoscience Center, University of Jyvaskyla, FI-40014 University of Jyvaskyla, Finland

Multiferroics have been seen as a disruptive building block for technological applications. Recently, evidence of multiferroicity has been provided in monolayer NiI_2. However, the multiferroic order in monolayer NiI_2 has not been characterized yet. In order to address this issue, here we perform an atomic-scale visualization of monolayer NiI_2.

This is achieved by exploiting the atomic-scale magnetoelectric coupling in NiI_2 to image spin-spiral multiferroics via scanning tunneling microscope (STM) experiments. Moreover, we directly show external electric field control of the multiferroic domains. Our result demonstrates a novel methodology to analyze and characterize the magnetic and electric orders in this type of multiferroics materials.

MA 31.10 Wed 17:30 EB 407

Ptychographic imaging of multiferroic domains in freestanding $BiFeO_3$ films — •Tim A. Butcher[1], Nicholas W. Phillips[1], Chia-Chun Wei[2], Carlos A. F. Vaz[1], Armin Kleibert[1], Simone Finizio[1], Jan-Chi Yang[2,3], Shih-Wen Huang[1], and Jörg Raabe[1] — [1]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan — [3]Center for Quantum Frontiers of Research & Technology (QFort), National Cheng Kung University, Tainan 70101, Taiwan

The multiferroic domains in freestanding bismuth ferrite films were imaged with the synchrotron technique of soft X-ray ptychography, which can achieve a high spatial resolution in the order of 5 nm. The ferroelectric domains show a linear dichroic contrast at the Fe L_3 edge, while the antiferromagnetic spin cycloid was reconstructed from its diffraction peak under resonant scattering conditions. The results directly visualise the strong magnetoelectric coupling and the changes in the multiferroic domain patterns with varying film thickness.

MA 31.11 Wed 17:45 EB 407

Imaging the antiferromagnetic domains in $LiCoPO_4$ via the optical magnetoelectric effect — •Boglárka Tóth[1], Vilmos Kocsis[2,3], and Sándor Bordács[1,4] — [1]Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Hungary — [2]RIKEN Center for Emergent Matter Science (CEMS), Japan — [3]Institut für Festkörperforschung, Leibniz IFW-Dresden, Germany — [4]ELKH-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Hungary

$LiCoPO_4$ is a widely researched compound. Not only it is a very promising candidate as a cathode material for lithium-ion batteries, but also shows strong linear magnetoelectric (ME) effect. Its two sublattice antiferromagnetic (AFM) order emerging below $T_N = 21.7$ K breaks spatial inversion and time-reversal symmetries, and correspondingly gives rise to the ME effect. We investigated the optical ME effect of $LiCoPO_4$, which manifests in the so-called directional dichroism; the light absorption difference for counter propagating beams. The absorption of polarized light in the sample was measured after poling, i.e., field-cooling the sample across T_N in external E and B fields simultaneously, to stabilize one or the other AFM domain. There is a finite absorption difference for the two AFM domains, which, considering they are time-reversal pairs of each other, we interpret as directional dichroism. A simple transmission microscope setup was constructed to image the AFM domains based on their absorption difference.

MA 32: $SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor: Poster (joint session TT/KFM/MA/O)

Strontium titanate ($SrTiO_3$) is a paradigmatic material that plays an important role in various fields of solid-state physics, surface science and catalysis: The pure bulk phase is a wide-band-gap semiconductor that upon cooling becomes a textbook quantum paraelectric. When slightly doped, $SrTiO_3$ turns into a Fermi-liquid-type metal that becomes superconducting at extremely low charge carrier density. $SrTiO_3$-based surfaces and interfaces host un-conventional electronic states such as quasi-two-dimensional electron liquid, magnetism and superconductivity. Despite intensive studies over the past decades, $SrTiO_3$ continues to reveal surprising new phenomena that challenge the established views on this material. To this end achieving light-induced nonequilibrium states and the recent preparation of a 2D oxide based on $SrTiO_3$ opens new playgrounds for research. This Focus Session will present exciting developments in the study of electronic states that are based on the peculiar properties of $SrTiO_3$.

Please note that this Focus Session comprises four parts: Posters are presented within the TT poster session TT58, Wed 15:00-18:00, poster area E. Invited talks are compiled in the session TT62 (Thursday, 9:30 to 12:45, H0104), Contributed talks will be presented in sessions TT72 (Thursday 15:00-18:00, H0104) and TT83 (Fri 9:30-12:30, H0104).

Organizers: Rossitza Pentcheva, University of Duisburg-Essen, Marc Scheffler, University of Stuttgart

Time: Wednesday 15:00–18:00 Location: Poster E

MA 32.1 Wed 15:00 Poster E

Optical conductivity of superconducting Nb:$SrTiO_3$ in magnetic fields at GHz frequencies — •Cenk Beydeda[1], Markus Thiemann[1], Martin Dressel[1], Hans Boschker[2], Jochen Mannhart[2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart

Doped $SrTiO_3$ was among the first unconventional superconductors, the application of the BCS theory is questionable due to the small Fermi energy. Here we present the optical conductivity ($1-30\,\mathrm{GHz}$) of superconducting Nb:$SrTiO_3$ in magnetic field. We observe features typical of an s-wave single-gap dirty type II superconductor. We attribute a kink in the magnetic field dependence to 2 distinct superconducting bands. We observe values of the real part of the optical conductivity exceeding the normal state value multiple times for rising magnetic field. Excessive losses at low frequency $hf \ll 2\Delta$ in dependence of temperature are a known feature of superconductivity and a result of coherence effects of the Cooper pairs in the superconducting state (coherence peak). The excessive losses we observe with rising magnetic field are substantially different from the coherence peak, especially in magnetic field dependence and absolute values. As far as we know, excessive losses of this type were not observed in any other superconductor. It is not clear whether Nb:$SrTiO_3$ is the only material that can show excessive losses of this type. We present an interpretation of our data in terms of Caroli-de Gennes-Matricon modes in the vortex state, reproducing the effect of excessive losses qualitatively.

MA 32.2 Wed 15:00 Poster E

Ultrafast second harmonic generation spectroscopy of $SrTiO_3$ surfaces and interfaces — Mahendra Kabbinahithlu, Newsha Vesalimahmoud, Tobias Lojewski, Ping Zhou, Katharina Ollefs, and •Andrea Eschenlohr — Faculty of Physics and CENIDE, University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Perovskite oxide heterostructures can exhibit properties at their interfaces that are very different from the bulk, for example a two-dimensional electron gas [1]. These properties emerge from charge carrier localization or charge transfer, which motivates an interface-sensitive analysis of the charge configuration and charge carrier dynamics. Second harmonic generation (SHG) spectroscopy is an interface-sensitive probe in centrosymmetric materials, suitable for the investigation of $SrTiO_3$-based heterostructures [2]. We perform pump-probe SHG spectroscopy with < 30 fs time resolution in the visible wavelength range (1.9-2.5 eV) at $SrTiO_3(001)$ surfaces as well as $LaTiO_3/SrTiO_3$ heterostructures, and discuss the polarization-, wavelength- and time-dependence of the observed SHG response.

[1] H. Y. Hwang, Y. Iwasa, M. Kawasaki, B. Keimer, N. Nagaosa, Y. Tokura, Nat. Mater. **11**, 103 (2012).
[2] A. Rubano, D. Paparo, Materials **16**, 4337 (2023).

MA 32.3 Wed 15:00 Poster E

Low-temperature GHz response of quantum paraelectrics $SrTiO_3$ and $KTaO_3$ — Vincent T. Engl, Nikolaj G. Ebensperger, Cenk Beydeda, Lars Wendel, Marius Tochtermann, Ilenia Neureuther, Ishan Sarvaiya, Martin Dressel, and •Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

The low-temperature dielectric properties of $SrTiO_3$ and $KTaO_3$ are characteristic of their quantum paraelectric nature: upon cooling, the real part ϵ_1 of the dielectric function strongly increases, but eventually levels off at high values of ≈ 20000 for $SrTiO_3$ and ≈ 4000 for $KTaO_3$. In particular for $SrTiO_3$ it is very demanding to combine such dielectric bulk material with conventional GHz circuitry. We present superconducting coplanar Nb resonators on $SrTiO_3$ and $KTaO_3$ substrates, where in the case of $SrTiO_3$ we employ a distant flip chip geometry. Taking advantage of several resonator modes, we determine the dielectric properties of the two materials at frequencies around 1 GHz and at temperatures down to 25 mK. We thus access regimes of frequency and temperatures, where the dielectric properties of $SrTiO_3$ and $KTaO_3$ have barely been studied.

For the case of $SrTiO_3$, we find an unexpected temperature dependence of the real part ϵ_1 of the dielectric constant: at temperatures below 5 K, where ϵ_1 is expected to vary little upon further cooling, we find a clear maximum around 3 K and a weak minimum around 200 mK. We also observe a strong suppression of microwave losses in both $SrTiO_3$ and $KTaO_3$ for temperatures down to the mK range.

MA 32.4 Wed 15:00 Poster E

ferromagnetic two-dimensional electron gas in oxide interfaces — •Yu Chen[1], Maria D'Antuono[1,2], Martando Rath[1], Cinthia Piamonteze[3], Daniele Preziosi[4], Benoit Jouault[5], Daniela Stornaiuolo[1,2], and Marco Salluzzo[1] — [1]CNR-SPIN, Napoli, Italy — [2]Università di Napoli "Federico II", Italy — [3]Photon Science Division, Paul Scherrer Institut, Switzerland — [4]Université de Strasbourg, CNRS, IPCMS UMR, France — [5]Laboratoire Charles Coulomb, UMR 5221, CNRS, Université de Montpellier, France

Interfacial inversion symmetry breaking triggers novel phenomena not observed in bulk materials, such as unconventional superconductivity and magnetism. Here, we report on the realization of ferromagnetic two-dimensional electron gas (2DEG) at (001) and (111) interfaces between $LaAlO_3$, $EuTiO_3$, and $SrTiO_3$. At variance with the octahedral and quasi-octahedral symmetry in bulk $SrTiO_3$ and (001) interface, trigonal crystal field is reconstructed at (111) interface. The experiments of transport, magnetic and x-ray spectroscopy indicate that the filling of Ti $3d$ bands in the $EuTiO_3$ layer and at the interface with $SrTiO_3$ induces an exchange interaction between Eu-$4f^7$ magnetic moments. We observe carrier density-dependent ferromagnetic correlations and anomalous Hall effect, sizable in-plane orbital moment possibly related to Ti-$3d$ electrons occupying bands with the main $3d_{xz,zy}$ and a_{1g} orbital characters at (001) and (111) interfaces, respectively. Our findings show intriguing interplay between ferromagnetism, spin-orbit coupling, and symmetry breaking at oxide 2DEG, serving as a guide for the materials design of advanced spintronics.

MA 32.5 Wed 15:00 Poster E

Role of excitonic effects in optical and x-ray absorption spectroscopy of $SrTiO_3$: insights from a combined first principles and many-body theory approach — •V. Begum-Hudde[1], M. E. Gruner[2], and R. Pentcheva[2] — [1]University of Illinois Urbana-Champaign, USA. — [2]University of Duisburg-Essen, Duisburg, Germany.

We present a comprehensive study of the optical[1] and x-ray absorption spectrum[2] (XAS) in the paradigmatic oxide, $SrTiO_3$. Our results demonstrate that inclusion of the quasiparticle effects with single-shot G_0W_0 as well as the electron-hole (e-h), and electron-(core)hole interactions by solving the Bethe-Salpeter Equation (BSE) is integral to accurately describe both the valence and core electron excitations. For the optical spectra, the effect of the exchange-correlation functional is observed to progressively reduce from 1.5 eV variance in the onset of the spectrum in the independent particle picture to 0.3 eV upon inclusion of excitonic corrections. The Ti-$L_{2,3}$ XAS edge is concurrent with experiment w.r.t. the energetic positions of the four-peak structure which is characteristic of Ti octahedral coordination in $SrTiO_3$. We also analyze the origin of prominent peaks in the spectra and identify the orbital character of the relevant contributions by projecting the e-h coupling coefficients from the BSE eigenvectors on the band structure. The spatial distribution of the first bound exciton wave function of the O K edge exhibits an intriguing two-dimensional spread in the x-y plane despite the three-dimensional nature of the material.

[1] Phys. Rev. Mater. **3**, 065004 (2019)
[2] Phys. Rev. Res. **5**, 013199 (2023)

MA 32.6 Wed 15:00 Poster E

Boosting the Edelstein effect of two-dimensional electron gases by ferromagnetic exchange — •Gabriel Lazrak[1], Annika Johansson[2], Börge Göbel[2,3], Ingrid Mertig[2,3], Agnès Barthélémy[1], and Manuel Bibès[1] — [1]Laboratoire Albert Fert, Université Paris-Saclay, CNRS, Thales, Palaiseau, FRANCE — [2]Max Planck Institute of Microstructure Physics, Halle, GERMANY — [3]Martin Luther University Halle-Wittenberg, Halle, GERMANY

In this work, we show that making STO 2DEGs ferromagnetic significantly boosts the conversion efficiency of charge and spin currents through direct and inverse Edelstein effects (EE/IEE). Starting from the experimental band structure of non-magnetic SrTiO3 2DEGs, we mimic magnetic exchange coupling by introducing an out-of-plane Zeeman term in a tight-binding model. We then calculate the band structure and spin textures for increasing internal magnetic fields and compute the Edelstein effect using a semiclassical Boltzmann approach. The conversion efficiency initially rises with magnetic field strength, reaching a maximum before declining. This behavior results from the interplay between exchange coupling and the effective Rashba interaction. Our experimental focus is on the 2DEG at the SrTiO3/EuO interface to introduce ferromagnetism into the system.

MA 32.7 Wed 15:00 Poster E

Impact of a Si(001) substrate on the electronic reconstruction and two-dimensional electron gas formation at $LaTiO_3/SrTiO_3(001)$ — •Andri Darmawan and Rossitza Pentcheva — Department of Physics, University of Duisburg-Essen

The two-dimensional electron gas (2DEG) formed at oxide interfaces e.g. between the band insulator $SrTiO_3$ and the Mott insulator $LaTiO_3$ has attracted a lot of attention [1]. However, despite the high carrier density at the interface, the carrier mobility is lower compared to semiconductor materials. A strategy to overcome this shortcoming is the integration of the oxide system on a semiconductor substrate [2]. Based on density functional theory calculations with a Hubbard U term we modeled $LaTiO_3/SrTiO_3(001)$ with and without a Si(001) substrate. We explore systematically the sample geometry and the effect of the termination to Si(001) on the electronic reconstruction at the $LaTiO_3/SrTiO_3(001)$ interface. The comparison between the two systems indicates lower effective masses and consequently higher mobility of the 2DEG at $LaTiO_3/SrTiO_3/Si(001)$.

Funding by DFG within CRC1242 and computational time at the Leibniz Supercomputer Center (project pr87ro) are gratefully acknowledged.

[1] A. Ohtomo et al., Nature 419, 378 (2002)
[2] E. N. Jin et al., APL Mater. 2, 116109 (2014)

MA 33: Focus Session: $SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor I (joint session TT/KFM/MA/O)

Strontium titanate ($SrTiO_3$) is a paradigmatic material that plays an important role in various fields of solid-state physics, surface science and catalysis: The pure bulk phase is a wide-band-gap semiconductor that upon cooling becomes a textbook quantum paraelectric. When slightly doped, $SrTiO_3$ turns into a Fermi-liquid-type metal that becomes superconducting at extremely low charge carrier density. $SrTiO_3$-based surfaces and interfaces host un-conventional electronic states such as quasi-two-dimensional electron liquid, magnetism and superconductivity. Despite intensive studies over the past decades, $SrTiO_3$ continues to reveal surprising new phenomena that challenge the established views on this material. To this end achieving light-induced nonequilibrium states and the recent preparation of a 2D oxide based on $SrTiO_3$ opens new playgrounds for research. This Focus Session will present exciting developments in the study of electronic states that are based on the peculiar properties of $SrTiO_3$.

Please note that this Focus Session comprises four parts: Posters are presented within the TT poster session TT58 (Wed 15:00-18:00, poster area E). Invited talks are compiled in the session TT62 (Thursday, 9:30 to 12:45, H0104), Contributed talks will be presented in sessions TT72 (Thursday 15:00-18:00, H0104) and TT83 (Fri 9:30-12:30, H0104).

Organizers: Rossitza Pentcheva, University of Duisburg-Essen, Marc Scheffler, University of Stuttgart

Time: Thursday 9:30–12:45 Location: H 0104

Invited Talk MA 33.1 Thu 9:30 H 0104
Ferroelectricity and Superconductivity in $SrTiO_3$ — •Susanne Stemmer — University of California, Santa Barbara, USA

Polar superconductors have attracted significant interest for their potential to host unconventional superconductivity. One candidate is doped strontium titanate ($SrTiO_3$), which can undergo successive ferroelectric and superconducting transitions. Recent experimental observations of a factor of two enhancement of the superconducting transition temperature in ferroelectric samples and the fact that both ferroelectricity and superconductivity vanish around the same carrier density, hint at common physical interactions relevant for both phenomena. We will discuss our understanding of ferroelectricity in strained $SrTiO_3$ films, and experiments aimed at elucidating the connection between superconductivity and ferroelectricity.

Although the ferroelectric transition of strained, undoped $SrTiO_3$ is usually described as a classic displacive transition, we show that it has pronounced order-disorder characteristics. Increasing the carrier concentration causes polar nanodomains to break up into smaller clusters. (Local) polar order appears to be essential to the superconducting state. For example, in strained $SrTiO_3$ films, suppression of superconductivity is correlated to the destruction of the (global) ferroelectric state, either by overdoping, by decreasing the film thickness or by alloying large amounts of a rare earth ion. We discuss how the length scale of polar order emerges as an important parameter in controlling the superconductivity of $SrTiO_3$.

Invited Talk MA 33.2 Thu 10:00 H 0104
Dilute superconductivity in doped strontium titanate — •Kamran Behnia — LPEM-ESPCI, Paris, France

Dilute superconductivity survives in bulk strontium titanate when the Fermi temperature falls well below the Debye temperature. The onset of the superconducting dome is dopant dependent. The threshold density fpr superconductivity is much lower for mobile electrons introduced by removing oxygen atoms compared to those brought by substituting Ti with Nb. Our study of quantum oscillations reveals a difference in the band dispersion between the dilute metals made by these doping routes and our band calculations demonstrate that the rigid band approximation does not hold when mobile electrons are introduced by oxygen vacancies. We identify the band sculpted by these vacancies as the exclusive locus of superconducting instability in the ultradilute limit.

Invited Talk MA 33.3 Thu 10:30 H 0104
Polarons and Excitons in quantum-paraelectric $SrTiO_3$ — •Cesare Franchini — University of Vienna & Bologna

$SrTiO_3$ stands as one of the most extensively investigated materials, captivating attention due to its distinctive electronic properties emerging from its quantum paraelectric nature. Positioned on the cusp of various collective phases, this material holds significant potential for exploitation in electronic and optical applications. In this presentation, we delve into the biphonon collective behaviors and quasiparticle properties of $SrTiO_3$ in both bulk and reduced dimensions, leveraging a combination of single-particle and many-body methods supported by machine learning techniques. Our exploration commences with an examination of temperature-dependent quantum and anharmonic effects employing a synergy of machine-learned potentials and the stochastic self-consistent harmonic approximation [1,2]. Shifting focus, we investigate the electron-phonon-driven formation of polarons, scrutinizing the interplay between spatially localized small polarons and dispersive large polarons in both bulk $SrTiO_3$ [3,4] and on the bulk-terminated $SrTiO_3(001)$ surface [5,6]. In conclusion, our study delves into the optical and excitonic properties, with particular emphasis on the emergence of strongly bound excitonic peaks in the monolayer limit [7,8].

[1] Adv. Quantum Technol. 6 (2023) 2200131
[2] Phys. Rev. Mater. 7 (2023) L030801
[3] Phys. Rev. B 91 (2015) 085204
[4] npj Computational Materials 125 (2022)
[5] Phys. Rev. Mater. 3, 034407 (2019); Phys. Rev. B 103 (2021) L241406
[6] Phys. Rev. Mater. 7 (2023) 064602
[7] Phys. Rev. Mater. 5 (2021) 074601
[8] arXiv:2303.14830

15 min. break

Invited Talk MA 33.4 Thu 11:15 H 0104
Controlling ferroelectrics with light — •Andrea Cavalleri — Max Planck Institute for the Structure and Dynamics of Matter, Hamburg — Department of Physics, University of Oxford

I will discuss how irradiation of ferroelectrics with intense, far and mid-infrared pulses, which are made resonant with certain phonon modes, can be used to manipulate the ferroelectric polarization. Two cases have been identified so far. On the one side, irradiation of a low temperature ferroelectric phase (e.g. in $LiNbO_3$) can achieve switching of the polarization. In incipient ferroelectric phases (e.g. in $SrTiO_3$), can lead to the formation of a long range ordered phase with stronger ferroelectricity than the paraelectric ground state. The microscopic physics of these phenomena are only in part clear, and I will discuss progress in this area.

Invited Talk MA 33.5 Thu 11:45 H 0104
Terahertz electric field driven dynamical multiferroicity in $SrTiO_3$ — •Stefano Bonetti — Ca' Foscari University of Venice, Venice, Italy

In recent years, the ultrafast dynamical control and creation of novel ordered states of matter not accessible in thermodynamic equilibrium is receiving much attention. Among those, the theoretical concept of dynamical multiferroicity has been introduced to describe the emergence of magnetization by means of a time-dependent electric polarization in non-ferromagnetic materials. However, the experimental verification of this effect is still lacking. Here, we provide evidence of room temperature magnetization in the archetypal paraelectric perovskite $SrTiO_3$ due to this mechanism. To achieve it, we resonantly drive the infrared-active soft phonon mode with intense circularly polarized terahertz electric field, and detect a large magneto-optical Kerr effect. A simple model, which includes two coupled nonlinear oscillators whose forces and couplings are derived with ab-initio calculations using self-consistent phonon theory at a finite temperature, reproduces qualitatively our experimental observations on the temporal and frequency domains. A quantitatively correct magnitude of the effect is obtained when one also considers the phonon analogue of the reciprocal of the Einstein - de Haas effect, also called the Barnett effect, where the total angular momentum from the phonon order is transferred to the electronic one. Our findings show a new path for designing ultrafast magnetic switches by means of coherent control of lattice vibrations with light.

MA 33.6 Thu 12:15 H 0104

Emergence of a quantum coherent state at the border of ferroelectricity in $SrTiO_3$ — •Matthew Coak[1,2], Charles Haines[2], Cheng Liu[2], Stephen Rowley[2,3], Gilbert Lonzarich[2], and Siddharth Saxena[2] — [1]School of Physics and Astronomy, University of Birmingham, Birmingham, UK — [2]Cavendish Laboratory, University of Cambridge, Cambridge, UK — [3]Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil

$SrTiO_3$ exists on the border of ferroelectricity in the vicinity of a quantum critical point (QCP). It is this proximity to a quantum critical point and the fluctuations associated with it which are responsible for $SrTiO_3$'s strikingly non-classical dielectric susceptibility.

I will discuss our results utilising ultra-high precision measurements of the the dielectric susceptibility to demonstrate an unconventional quantum paraelectric state exhibiting ‘order by disorder’ - a fluctuation-induced enhancement of electric polarization up to a coherence temperature T^*. We show that in the vicinity of T^* this phenomenon can be understood quantitatively in terms of the hybridization of the critical electric polarization field and the volume strain field of the lattice.

We argue that this coherent optical-acoustic phonon state emerges from the QCP and is critical to our understanding of the mechanisms behind the quantum criticality and the phenomena resulting from it. At still lower temperatures, well below T^*, we observe a breakdown of this unconventional form of quantum paraelectricity and the emergence of a new instanton liquid phase.

MA 33.7 Thu 12:30 H 0104

Dynamics of the critical phonon modes in quantum paraelectric $SrTiO_3$ — •Shiyu Deng[1,2], Charles S. Haines[1,3], Matthew J. Coak[1,4], Alexandre Ivanov[2], Andrea Piovano[2], Andrew R. Wildes[2], and Siddharth S. Saxena[1] — [1]Cavendish Laboratory, University of Cambridge — [2]Institut Laue-Langevin — [3]University of East Anglia — [4]University of Birmingham

The proximity of $SrTiO_3$ to a ferroelectric quantum critical point (FE QCP) has become a promising new branch of the study of quantum critical phenomena. New forms of quantum order have been reported in SrTiO3 different from the quantum paraelectric state via dielectric measurements.

We report our recently performed triple-axis inelastic neutron scattering experiments on single-crystal $SrTiO_3$ at the temperature and pressure region of interest. These were the first direct measurements deep into the enigmatic 'quantum polar-acoustic state' in the vicinity of the FE QCP. Measurements are taken at and around $q = 0$ in multiple directions in reciprocal space to explore the transverse acoustic and soft optical phonon modes and their hybridization. In addition, we explore how pressure affects the underlying phonon modes in $SrTiO_3$. Our observations address directly the coupling of the soft optical mode with the acoustic phonons, and its response to external pressure. We believe this could help us understand the importance of anharmonic lattice dynamics and quantum fluctuations in $SrTiO_3$.

MA 34: Focus Session: Emerging Magnetic Phenomena from Chiral Phonons I (joint session MA/TT)

Contemporary efforts in spintronics focus on utilizing and controlling electronic angular momentum for possible applications in data storage and processing. Only recently, an alternative has arisen in the form of angular momentum generated by circularly polarized (chiral) phonons. Chiral phonons have been shown to lead to a variety of novel magnetic phenomena, including a phonon Hall, phonon Einstein-de Haas, phonon Barnett, and phonon Zeeman effect. Phonon angular momentum can be utilized to control the magnetic state of solids and even to induce magnetization in nonmagnetic materials. These discoveries make the angular momentum of chiral phonons a promising tool for the control of magnetic materials and an emerging quantity of interest for spintronic applications. The goal of this focus session is to highlight topical research on novel magnetic phenomena arising from chiral phonons and to connect this rapidly developing field to the broader audience working in magnetism and spintronics.

Coordinators: Sebastian T. B. Goennenwein, Universität Konstanz, sebastian.goennenwein@uni-konstanz.de Ulrich Nowak, Universität Konstanz, ulrich.nowak@uni-konstanz.de

Time: Thursday 9:30–12:15 Location: H 1058

Invited Talk MA 34.1 Thu 9:30 H 1058

Giant effective magnetic fields from chiral phonons — •Dominik M. Juraschek — Tel Aviv University, Tel Aviv 6997801, Israel

Chiral phonons conventionally describe circularly polarized lattice vibrations that carry angular momentum. In dielectric materials, the circular motions of the ions create a macroscopic magnetic field when driven with an ultrashort laser pulse, which has previously been shown to reach the order of millitesla. Here, we predict that this magnetic field can effectively reach up to the tesla scale, when enhanced by orbit-lattice coupling [1,2]. Our predictions have been experimentally confirmed in a recent study [3]. We demonstrate theoretically that these giant phono-magnetic fields can be utilized to generate nonequilibrium spin configurations in antiferromagnets, leading to a light-induced weak ferromagnetic state [4]. Finally, whereas the above phenomena are based on circularly polarized chiral phonons, we further demonstrate that the crystal structure can be transiently made chiral with linearly polarized phonons that are quasistatically displaced by nonlinear phonon coupling [5]. These “linearly polarized chiral phonons” make it possible to create chiral crystal structures on demand with implications for chiral magnetic and electronic properties.

[1] Juraschek et al., PRResearch, 4, 013129 (2022) [2] S. Chaudhary, D. M. Juraschek, et al., arXiv:2306.11630 (2023) [3] J. Luo et al., Science 382, 698 (2023) [4] T. Kahana, D. A. Bustamante Lopez, and D. M. Juraschek, arXiv:2305.18656 (2023) [5] C. Romao and D. M. Juraschek, arXiv:2311.00824 (2023)

Invited Talk MA 34.2 Thu 10:00 H 1058

Chiral phonons in quantum materials revealed by the thermal Hall effect — •Gael Grissonnanche — Ecole Polytechnique, Palaiseau, France

It is becoming surprisingly clear that phonons can produce a large thermal Hall effect across a wide range of quantum materials, from cuprate superconductors [1,2] to titanates [3], iridates [4], and frustrated magnets [5]. The thermal Hall effect represents the deflection of a heat current by a perpendicular magnetic field. It is usually interpreted as coming from mobile hot electrons deflected by the Lorentz force. While trivial in metals, this effect is now found in insulators, and phonons that carry no charge are responsible for it. Phonons are the most common low-energy excitations in solids. Yet the handedness they acquire in a magnetic field * which triggers the thermal Hall effect * remains an enigma. In this talk, I will present the results that have led to the emergence of a new field of research aimed at discovering the origin of the thermal Hall effect of phonons and how this might relate to the question of chiral phonons measured by other probes.

[1] Grissonnanche et al. Nature 571, 376 (2019) [2] Grissonnancheet al. Nat. Phys. 16, 1108 (2020) [3] Li et al. Phys. Rev. Lett. 124, 105901 (2020) [4] Ataei et al. Nat. Phys. (2023) [5] Lefrançois et al. Phys. Rev. X 12, 021025 (2022)

Invited Talk MA 34.3 Thu 10:30 H 1058

Phonon chirality and thermal Hall transport — •Benedetta Flebus[1] and Allan H. MacDonald[2] — [1]Department of Physics, Boston College, 140 Commonwealth Avenue, Chestnut Hill, Massachusetts 02467, USA — [2]Department of Physics, the University of Texas at Austin, Austin, Texas 78712, USA

In recent years, a rapidly increasing amount of studies has reported novel physical phenomena arising from lattice vibrations that carry angular momentum, i.e., chiral phonons. In this talk, I will discuss both intrinsic and extrinsic sources of chiral phonon transport. First, I will show that in ionic crystals a phonon Hall viscosity contribution can emerge as a result of the Lorentz forces on moving ions [1]. I will then explain how phonon scattering from defects that break time-reversal symmetry, such as charged impurities, can yield giant thermal Hall effects that are consistent with recent experimental observations [2].

[1] B. Flebus and A. H. MacDonald, The phonon Hall viscosity of ionic crystals, Phys. Rev. Lett. (in press). [2] B. Flebus and A. H. MacDonald, Charged defects and phonon Hall effects in ionic crystals, Phys. Rev. B 105 (22), L220301 (2022).

15 min. break

Invited Talk MA 34.4 Thu 11:15 H 1058

Orbital magnetic moment of phonons in diamagnetic and paraelectric perovskites — Filip Kadlek[1], Christelle Kadlek[1], •Martina Basini[2,3], Sergey Kovalev[4], Jan-Christoph Deinert[4], Stefano Bonetti[1,5], and Stanislav Kamba[1] — [1]Institute of Physics of the Czech Academy of Sciences, Praha, Czech Republic — [2]Department of Physics, Stockholm University, Stockholm, Sweden — [3]Deparment of Materials and Nanophysics, KTH Royal Institute of Technology, Stockholm Sweden — [4]Helmholz Zentrum Dresden-Rossendorf, Germany — [5]Department of Molecular Sciences and Nanosystems, Ca' Foscari University of Venice, Venice, Italy

In the present work, we demonstrate transient magnetism in $KTaO_3$ induced by chiral phonons. In particular, the infrared-active soft phonon was circularly excited by means of intense quasi-monochromatic THz pulses produced by the TELBE facility and the magnetic moment was probed by magneto-optical Faraday effect. The evidence will be compared with our previous results on $SrTiO_3$. We anticipate that, contrary to $SrTiO_3$, $KTaO_3$ does not undergo any structural phase transition at low temperature so that we could efficiently excite the soft phonon below 100K, where the phonon effective charge is larger and a higher value of the induced orbital magnetic moments per unit cell is expected.

Invited Talk MA 34.5 Thu 11:45 H 1058

Spin-lattice coupling in multiscale modeling — •Markus Weissenhofer[1,2], Sergiy Mankovsky[3], Svitlana Polesya[3], Hannah Lange[3], Akashdeep Kamra[4], Hubert Ebert[3], and Ulrich Nowak[5] — [1]Uppsala University, Uppsala, Sweden — [2]Freie Universität Berlin, Berlin, Germany — [3]LMU Munich, Munich, Germany — [4]Universidad Autónoma de Madrid, Madrid, Spain — [5]University of Konstanz, Konstanz, Germany

In recent years, it has been shown that it is not only possible to transfer angular momentum from the spin system to the lattice on ultrashort time scales, but also that this process can be reversed by using circularly polarized terahertz light pulses [1].

To contribute to the understanding of angular momentum transfer between spin and lattice degrees of freedom, we have developed a theoretical multiscale framework for spin-lattice coupling [2], which is linked to ab-initio calculations on the one hand and magnetoelastic continuum theory on the other. Here I will discuss how this framework can be used to calculate magnon-phonon coupling parameters, emphasizing the importance of a Dzyaloshiskii-Moriya type interaction for angular momentum transfer in iron, and to perform simulations to study the combined magnetic and mechanical motion of ferromagnetic nanoparticles.

[1] Dornes et al., Nature (London) 565, 209 (2019); Tauchert al., Nature (London) 602, 73 (2022); Luo et al., Science 382, 698 (2023). [2] Mankovsky et al., PRL 129, 067202 (2022); Weißenhofer et al., PRB 108, L060404 (2023).

MA 35: Spin Transport and Orbitronics, Spin-Hall Effects I (joint session MA/TT)

Time: Thursday 9:30–12:45 Location: H 2013

MA 35.1 Thu 9:30 H 2013

Fluctuation mediated spin-orbit torque enhancement in the noncollinear antiferromagnet Mn3Ni0.35Cu0.65N — Arnab Bose[1], Aga Shahee[1], Tom G. Saunderson[1], •Adithya Rajan[1], Dongwook Go[2], Aurélien Manchon[3], Yuriy Mokrousov[1,2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, 52424 Jülich, Germany — [3]CINaM, Aix-Marseille Université, CNRS, Marseille, France

Spin fluctuations near magnetic phase transitions play a pivotal role in generating exotic phenomena. This study focuses on experimental investigation of temperature-dependent spin torques in the noncollinear antiferromagnet Mn3Ni0.35Cu0.65N (MNCN). Our findings reveal a significant and nontrivial temperature dependence of spin-orbit torques (SOT), peaking near MNCN's Néel temperature. This behavior cannot be explained by conventional scattering mechanisms of the SHE. Notably, a maximum SOT efficiency of 30 % is measured, surpassing that of commonly studied nonmagnetic materials like Pt. Theoretical calculations support a negligible SHE and a pronounced orbital Hall effect, explaining the observed spin torques. We propose a novel mechanism where fluctuating antiferromagnetic moments induce substantial orbital currents near the Néel temperature. These results provide a promising avenue for enhancing spin torques, with potential applications in magnetic memory.

MA 35.2 Thu 9:45 H 2013

First-principles calculation of the orbital current and orbital accumulation in metallic layers — •Daegeun Jo[1], Dongwook Go[2,3], Peter Oppeneer[1], and Hyun-Woo Lee[4] — [1]Department of Physics and Astronomy, Uppsala University, P.O. Box 516, SE-75120 Uppsala, Sweden — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [4]Department of Physics, Pohang University of Science and Technology, Pohang, South Korea

Recently, the orbital degree of freedom has emerged as a new element for the electrical control of magnetization in magnetic devices. Notably, magneto-optical measurements have demonstrated that the orbital angular momentum is accumulated by the orbital Hall effect in metallic films consisting of light elements such as Ti [Y.-G. Choi *et al.*, Nature **619**, 52-56 (2023)] and Cr [I. Lyalin *et al.*, Phys. Rev. Lett. **131**, 156702 (2023)]. However, the relationship between the orbital Hall current and the boundary orbital accumulation remains unclear. In this work, we present the theoretical calculations of the orbital Hall current and the current-induced orbital accumulation in various metallic films based on the first-principles calculations. We show that the orbital accumulation is properly described by considering the torque contribution from the crystal field in addition to the conventional orbital current.

MA 35.3 Thu 10:00 H 2013

Using first principles methods to describe spin-orbitronic and superconducting phenomena — •Tom G. Saunderson[1,2], Dongwook Go[1,2], Maria Teresa Mercaldo[3], Mario Cuoco[4], Martin Gradhand[1,5], and Yuriy Mokrousov[1,2] — [1]Institute of Physics, JGU, 55099 Mainz, Germany — [2]PGI and IAS, Forschungszentrum Jülich, Germany — [3]Universitá di Salerno, IT-84084 Fisciano, Italy — [4]CNR-SPIN, IT-84084 Fisciano (SA), Italy — [5]University of Bristol, Bristol BS8 1TL, UK

Recent advancements in orbitronics demonstrate remarkable efficiency gains using cost-effective materials [1], while spin-Hall mediated responses notably intensify near the superconducting transition [2]. Breaking inversion or time-reversal symmetry efficiently extracts these unconventional currents, however for material-specific predictions first principles techniques are essential. Although theoretical methods for orbital currents are well-established, first principles techniques for supercurrents are still in their infancy. This talk aims to explore two approaches. Firstly, we employ maximally localized Wannier functions to investigate the influence of p-d hybridizations on enhancing the orbital Rashba Edelstein effect on particular surfaces of known metallic systems. Secondly, we utilize a Green's function-based superconducting first principles code to induce unconventional triplet densities in superconductors featuring complex orbital degrees of freedom and inversion symmetry breaking. Such methods will pave the way for first principles-based modeling of superconducting spintronics. [1] Nature 619, 52 (2023) [2] ACS Nano 14, 15874 (2020)

MA 35.4 Thu 10:15 H 2013

Investigation of the topological transport properties for the MAB phase — •Fu Li, Ruiwen Xie, and Hongbin Zhang — Institute of Materials Science, Technology University of Darmstadt, 64287, Darmstadt, Germany

Compounds of MAB phases, i.e, Ternary transition metal borides with nano-laminated structures, have attracted significant attention due to their intriguing physical properties. In this work, we evaluate the topological transport properties(anomalous and spin Hall conductivities) of MAB compounds, aiming to uncover potential applications in the field of spintronics. After constructing the maximally localized Wannier functional automatically, the anomalous and spin Hall conductivities are obtained based on the Wannier interpolation. It is observed several compounds exhibit significant anomalous and spin Hall conductivities, which can be understood based on the underlying electronic structure. Furthermore, the influence of magnetization direction on spin Hall conductivity is studied for those compounds where the inversion symmetry is broken due to the antiferromagnetic ordering. We find that the magnitude of spin Hall conductivity can be tailored by the magnetization direction, offering possible applications in spintronics.

MA 35.5 Thu 10:30 H 2013

Unconventional Spin-Orbit Torques in CrPt3 — •Robin Klause[1], Yuxuan Xiao[2,3], Jonathan Gibbons[1,4], Axel Hoffmann[1], and Eric Fullerton[2] — [1]University of Illinois Urbana-Champaign — [2]University of California San Diego — [3]TDK Corporation — [4]Western Digital Corporation

Spin-orbit torques can efficiently control magnetization states using charge currents. However, with conventional spin-orbit torques, where charge current, spin current, and spin polarization are mutually perpendicular only in-plane magnetization parallel to the spin polarization can be switched field-free and deterministically. The topological semimetal CrPt3 has potential for generating unconventional spin-torques due to its ferrimagnetic ordering, topological band structure and high anomalous Hall conductivity. As CrPt3 exhibits ferrimagnetic behavior only in its chemically ordered phase while it is paramagnetic in its chemically disordered phase we can compare spin-torque generation in the two phases and investigate whether unconventional torques originate from the magnetic or crystal structure. We studied spin-torque generation in epitaxial CrPt3(110) films using angle dependent spin-torque ferromagnetic-resonance measurements with currents applied along specific crystal directions. We reveal unconventional spin-torques in both chemically ordered and disordered CrPt3 when current flows along the [1-11] and [-111] crystal directions. We conclude that the unconventional torque originates from the crystal order since these directions lack a mirror plane, allowing unconventional torques to be generated.

MA 35.6 Thu 10:45 H 2013

Spin and orbital Edelstein effect in a bilayer $SrTiO_3$ system — •Sergio Leiva[1], Börge Göbel[1], Jürgen Henk[1], Ingrid Mertig[1], and Annika Johansson[2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle (Saale), Germany. — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

The spin and orbital Edelstein effect have proved promising phenomenons to generate spin and orbital polarization from a charge current in systems without inversion symmetry [1-5]. The present work studies the current-induced spin and orbital magnetization in a $SrTiO_3/LaAlO_3$ interface with a tight-binding model and the semiclassical Boltzmann theory. We studied a monolayer, a pseudo-monolayer, and a bilayer system for the STO to replicate experimental data from ARPES. For the bilayer model [6], we compare the orbital effect from the atomic-centered approximation (ACA) and the modern theory of orbital magnetization (MTOM)[7]. We found that the orbital Edelstein effect from ACA is larger than the spin Edelstein effect [5] and the orbital effect from MTOM. This difference between ACA and MTOM shows the relevance of the modern theory for heterostructure systems.

[1] D. Go *et al.*, Sci. Rep. **7**, 46742 (2017)
[2] T. Yoda *et al.*, Nano Lett., **18**, 916 (2018).
[3] L. Salemi *et al.*, Nat. Commun. **10**, 5381 (2019)
[4] D. Hara *et al.*, Phys. Rev. B, **102**, 184404 (2020).
[5] A. Johansson *et al.*, Phys. Rev. Research, **3**, 013275 (2021).
[6] S. Leiva M. *et al.* arXiv:2307.02872 (2023).
[7] T. Thonhauser *et al.* Phys. Rev Lett. **95**, 137205 (2005).

MA 35.7 Thu 11:00 H 2013

Electrically induced angular momentum flow between separated ferromagnets — •Matthias Grammer[1,2], Richard Schlitz[3], Tobias Wimmer[1,2], Janine Gückelhorn[1,2], Luis Flacke[1,2], Sebastian T.B. Goennenwein[4], Rudolf Gross[1,2,5], Hans Huebl[1,2,5], Akashdeep Kamra[6], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, BAdW, Garching, Germany — [2]School of Natural Sciences, TUM, Garching, Germany — [3]Department of Materials, ETH Zürich, Zürich, Switzerland — [4]Department of Physics, University of Konstanz, Konstanz, Germany — [5]Munich Center for Quantum Science and Technology, München, Germany — [6]IFIMAC and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain

The transfer of angular momentum between electrons, magnons and phonons is pivotal for spintronic devices making use of angular momentum currents. Here, we demonstrate angular momentum transfer between two isolated ferromagnetic metal strips on diamagnetic substrates [1]. Experimentally we apply a DC charge current at one of the magnetic electrodes which is converted into an electronic spin current and consequently transfered to the magnonic system. Using the inverse process at the second electrode, we can detect the induced angular momentum flow between the electrodes up to micron distances. We attribute this transfer mechanism to dipolar and potentially phononic interactions.

[1] R. Schlitz et al., arXiv:2311.05290(2023)

15 min. break

MA 35.8 Thu 11:30 H 2013

Orbital Hall effect and orbital edge states caused by *s* electrons — •Oliver Busch, Ingrid Mertig, and Börge Göbel — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

An orbital current can be generated whenever an object has a translational degree of freedom and a rotational degree of freedom. In condensed matter physics, intra-atomic contributions to the transverse orbital transport, labeled the orbital Hall effect, rely on propagating wave packets that must consist of hybridized atomic orbitals [1]. However, interatomic contributions have to be considered as well because they give rise to an alternative mechanism for generating orbital currents [2].

As we show, even wave packets consisting purely of *s* electrons can transport orbital angular momentum if they move on a cycloid trajectory [3]. We introduce the kagome lattice with a single *s* orbital per atom as the minimal model for the orbital Hall effect and observe the cycloid motion of the electrons in the surface states.

[1] D. Go *et al.*, Physical Review Letters **121**, 086602 (2018)
[2] A. Pezo *et al.*, Physical Review B **106**, 104414 (2022)
[3] O. Busch *et al.*, Physical Review Research 5, 043052 (2023)

MA 35.9 Thu 11:45 H 2013

Spin-to-charge conversion in ferromagnetic heterostructures — •Misbah Yaqoob[1], Fabian Kammerbauer[2], Tom G.

Saunderson[2], Vitaliy I. Vasyuchka[1], Dongwook Go[3], Hassan Al-Hamdo[1], Gerhard Jakob[2], Yuriy Mokrousov[2,3], Mathias Kläui[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spin-orbit torques (SOTs) can be used for efficient control of magnetization and the electrical detection of spin dynamics through the inverse spin Hall effect (iSHE) [1]. We investigate spin-to-charge conversion in ferromagnetic heterostructures based on perpendicular magnetic anisotropy (PMA) multilayers of [Co/Ni] and [Co/Pt] that generate SOTs in adjacent CoFeB thin films with in-plane magnetic anisotropy (IPA). We extract the spin dynamics and SOTs [2] using vector network analyzer ferromagnetic resonance spectroscopy (VNA-FMR). In our experiments, we found that our multilayers generate SOTs comparable in magnitude to Pt, in agreement with first-principles calculations. Additionally, we observed a pronounced dependence of the SOT on the IPA CoFeB layer thickness.

[1] T. Jungwirth *et al.*, Nat. Mater. **11**, 382 (2012).
[2] A. J. Berger *et al.*, Phys. Rev. B **97**, 94407 (2018).

MA 35.10 Thu 12:00 H 2013

Modelling layer resolved spin-orbit torque assisted magnetization dynamics in Pt/Co bilayers — •Harshita Devda[1], Andras Deak[2], Leandro Salemi[3], Levente Rozsa[4], Laszlo Szunyogh[2], Peter M. Oppeneer[3], and Ulrich Nowak[1] — [1]University of Konstanz, Konstanz, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]Uppsala University, Uppsala, Sweden — [4]Wigner Research Centre for the Physics, Budapest, Hungary

Spin-orbit-torque(SOT) devices have acquired extensive attention for their unique features, encompassing low power consumption and efficient data storage capabilities. Recent discoveries of the Orbital Hall Effect and the Orbital Rashba-Edelstein Effect have added more intricacy to the understanding of magnetization switching mechanisms in these devices, especially in Nonmagnetic/Ferromagnet systems. To address this, we present a model for a Pt/Co bilayer system where we utilized Atomistic Spin Dynamics simulations, incorporating abinitio calculated interaction parameters mapped to the Hamiltonian and electrically induced moments from first-principles calculations. Our descriptive model reveals the Spin and Orbital Hall Effect as the dominant mechanism behind magnetization switching in Pt/Co at low electric field strengths. Conversely, there is a significant magnetization dependence of the interface-generated moments at high field, leading to counterintuitive anti-switching behaviour with enhanced layer-resolved behavior in the presence of orbital moments.

MA 35.11 Thu 12:15 H 2013

Investigating Orbital Hall Effect Materials for Efficient Magnetization Control with In-plane and Perpendicular Magnetic Anisotropic Ferromagnets — Rahul Gupta[1], •J. Omar Ledesma Martin[1,2], Chloe Bouard[2], Fabian Kammerbauer[1], Sylvain Martin[2], Gerhard Jakob[1], Marc Drouard[2], and Mathias Kläui[1,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Antaios, 35 Chemin du Vieux Chêne, 38240 Meylan, France — [3]Center for Quantum Spintronics, Department of Physics, Norwegian, University of Science and Technology, NO-7491 Trondheim, Norway

There is considerable potential in the Orbital Hall Effect (OHE) and the Spin Hall Effect (SHE) as electrical means for controlling the magnetization of spintronic devices. Here Ru stands out exhibiting an orbital Hall conductivity four times greater than that of Pt.

This work, assesses the efficiency of four distinct stacks in devices with perpendicular Magnetic Tunnel Junctions (MTJ). Following the formula Ta/OHE/Pt/[Co/Ni]3/Co/MgO/CoFeB/Ta/Ru, where the OHE materials are Ru, Nb, and Cr. Additionally, a sample wit Pt instead of OHE serves as a reference.

The results demonstrate an improvement in the Ru samples, exhibiting higher damping-like torque and lower switching current density compared to both the other samples and the Pt reference. These findings, including first-principle calculations, underscore the potential of Ru as an OHE material for enhancing the performance and power consumption of spintronic devices.

MA 35.12 Thu 12:30 H 2013

Unlocking the Potential of Rare-Earth Dichalcogenides for Topological Spintronics and Orbitronics — Mahmoud Zeer[1,2], Dongwook Go[1,3], •Peter Schmitz[1,2], Tom G. Saunderson[3], Wulf Wulfhekel[4], Stefan Blügel[1,2], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany — [2]Department of Physics, RWTH University, Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg-University, Mainz, Germany — [4]Institute of Quantum Materials and Technologies, Karlsruhe Institute of Technology, Karlsruhe, Germany

We investigate the electronic, magnetic and transport properties of rare-earth dichalcogenides, specifically monolayers of H-phase EuX2 and GdX2 (X = S, Se, Te), using first-principle methods. We show that this family of materials exhibits high magnetic moments, wide bandgaps, and significant anomalous, spin, and orbital Hall conductivities. While the hybridization of p- and f- states in EuX2 occurs just below the Fermi energy, GdX2 displays a non-trivial p-like spin-polarized electronic structure at the Fermi level, which results in manifestly p-based magnetotransport properties. We unravel the role of correlations and strain in influencing the position and hybridization character between the p-, d-, and f-states, which has a direct impact on the quantized Hall response. Our findings suggest that rare-earth dichalcogenides hold promise as a platform for topological spintronics and orbitronics. [1,2] [1] Physical Review Materials 6 (7), 074004 [2] arXiv preprint arXiv:2308.08207.

MA 36: Terahertz Spintronics II

Time: Thursday 9:30–10:45 Location: EB 202

MA 36.1 Thu 9:30 EB 202

Simulating the THz response of Mn_2Au — •Tobias Dannegger, Fynn Renner, and Ulrich Nowak — Fachbereich Physik, Universität Konstanz

The antiferromagnet Mn_2Au is one of very few materials whose symmetry allows for Néel spin orbit torques, which can be used to excite its magnetic order on ultrafast timescales with the electric field of a THz pulse, as has recently been demonstrated [1]. Its perfectly uncompensated coupling to ferromagnetic permalloy is a promising option for detecting its magnetic state [2], while still allowing for ultrafast switching dynamics [3]. Here, we use atomistic spin dynamics simulations with ab initio calculated parameters [4] to understand the THz response of Mn_2Au on a microscopic level and predict the conditions that allow for ultrafast THz-induced switching both in pure Mn_2Au and in bilayers coupled to permalloy.

[1] Y. Behovits et al., *Nat. Commun.* **14**, 6038 (2023).
[2] S. P. Bommanaboyena et al., *Nat. Commun.* **12**, 6539 (2021).
[3] J. Hirst et al., *Sci. Rep.* **13**, 12270 (2023).
[4] S. Selzer et al., *Phys. Rev. B* **105**, 174416 (2022).

MA 36.2 Thu 9:45 EB 202

Advancing the Efficiency of Spintronic Terahertz Frequency Conversion — •Hatice Nur Koyun[1], Ruslan Salikhov[1], Ciaran Fowley[1], Jürgen Lindner[1], Stephan Winnerl[1], Artur Erbe[1,2], Jürgen Fassbender[1,2], Manfred Helm[1,2], and Sergey Kovalev[1,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany — [3]Technische Universität Dortmund, 44227, Dortmund, Germany

Terahertz (THz) spintronics, operating on picosecond timescales, involves the generation and control of non equilibrium electron spin states within the THz frequency regime. Recent studies have shown that THz light can efficiently drive coherent spin currents in nanometer-thick ferromagnet (FM)/heavy-metal (HM) heterostructures, primarily due to demagnetization process of FM and the ultrafast spin Seebeck effect. Owing to the fact that the electron-phonon relaxation time is comparable (or smaller) to the period of a THz wave, the induced spin current from each half cycle of the THz wave results in THz second harmonic generation (TSHG) and THz optical rectification. In this study, we explore the potential of utilizing subwavelength-sized gold periodic arrays with a grating period smaller than the THz wavelength to enhance local spin currents, thereby improving the efficiency of THz frequency conversion.

MA 36.3 Thu 10:00 EB 202

Modeling superdiffusive spin current-induced terahertz emission from layered heterostructures — •Francesco Foggeti and Peter M. Oppeneer — Uppsala University, Uppsala, Sweden

In ultrafast spintronic teraherts emitters, THz radiation is generated by exciting an ultrafast spin current through femtosecond laser pulse in ferromagnetic-non magnetic heterostructures. Here, due to inverse spin Hall effect, the excited spin current results in an electromagnetic signal in the THz frequency range. Although an extensive phenomenological knowledge has been built through the last decade, a solid theoretical modeling that connects the generated signal to the laser induced-spin current is still incomplete. In this work, starting from general solutions to Maxwell equations, we model the electric field generated by a superdiffusive spin current in spintronic emitters. Additionally, effects due to the detector presence are also studied and taken into account, resulting in a good agreement between the predicted THz signal and the experimental measurements.

MA 36.4 Thu 10:15 EB 202

Light field-driven spin current generation for spintronic terahertz frequency multiplication — •Sergey Kovalev[1,2], Igor Ilyakov[2], Arne Brataas[3], Thales Oliveira[2], Alexej Ponomaryov[2], Jan Deinert[2], Olav Hellwig[2], Jürgen Fassbender[2], Jürgen Lindner[2], and Ruslan Salikhov[2] — [1]Fakultät Physik, Technische Universität Dortmund, Dortmund, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, Trondheim, Norway

Efficient generation and control of spin currents launched by terahertz (THz) radiation with subsequent ultrafast spin-to-charge conversion is the current challenge for the next generation of high-speed communication and data processing units. In this talk, we demonstrate that THz light can efficiently drive coherent angular momentum transfer in nanometer-thick ferromagnet/heavy-metal heterostructures. The coherently driven spin currents originate from the ultrafast spin Seebeck effect, caused by a THz-induced temperature imbalance in electronic and magnonic temperatures and fast relaxation of the electron-phonon system. Owing to the fact that the electron-phonon relaxation time is comparable with the period of a THz wave, the induced spin current results in THz second harmonic generation and THz optical rectification [1], providing a spintronic basis for THz frequency mixing and rectifying components.

[1] I. Ilyakov et al., Nature Communications 14, 7010 (2023)

MA 36.5 Thu 10:30 EB 202

Voltage-Controlled High-Bandwidth Terahertz Oscillators Based On Antiferromagnets — Mike Lund[1], Davi Rodrigues[2], Karin Everschor-Sitte[3], and •Kjetil Hals[1] — [1]Department of Engineering Sciences, University of Agder, 4879 Grimstad, Norway — [2]Department of Electrical and Information Engineering, Polytechnic University of Bari, 70125 Bari, Italy — [3]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

The terahertz (THz) technology gap refers to a frequency range of electromagnetic radiation in the THz regime where current technologies are inefficient for generating and detecting radiation. Here, we show that noncollinear antiferromagnets (NCAFM) with kagome structure host gapless self-oscillations whose frequencies are tunable from 0 Hz to the THz regime via electrically induced spin-orbit torques (SOTs) [1]. The auto-oscillations' initiation, bandwidth, and amplitude are investigated by deriving an effective theory, which captures the reactive and dissipative SOTs. We find that the dynamics strongly depends on the ground state's chirality, with one chirality having gapped excitations, whereas the opposite chirality provides gapless self-oscillations. Our results demonstrate that NCAFMs offer unique THz functional components, which could play a significant role in bridging the gap between technologies operating in the microwave and infrared regions.

[1] M. A. Lund, D. R. Rodrigues, K. Everschor-Sitte, and K. M. D. Hals, Phys. Rev. Lett. 131, 156704 (2023).

MA 37: Skyrmions III

Time: Thursday 9:30–13:00 Location: EB 301

MA 37.1 Thu 9:30 EB 301

Classical and quantum skyrmions in monoaxial chiral magnets — •Vladyslav Kuchkin[1,2], Stefan Liscak[1], Andreas Haller[1], Thomas Schmidt[1], and Nikolai Kiselev[3] — [1]University of Luxembourg — [2]University of Iceland — [3]Forschungszentrum Jülich

Chiral magnets represent a special type of magnetic materials with non-zero Dzyaloshinskii-Moriya interactions (DMI). The interplay between DMI and Heisenberg exchange interaction can stabilize a wide variety of magnetic textures: spin spirals, skyrmion lattices, isolated solitons, etc. In ordinary magnets, the DMI is isotropic, which fixes the chirality type of all such textures. However, if the DMI vanishes in certain spatial directions, magnetic solitons of different chiralities might be stable. In our theoretical work, we have demonstrated the existence of skyrmions and antiskyrmions in such monoaxial chiral magnets and studied the static and dynamic properties of these solitons. In particular, we showed that applying a rotating magnetic field of frequency ω leads to a motion of solitons with a velocity $v \sim \omega$. From the point of view of quantum skyrmions, monoaxial chiral magnets are a unique system in which skyrmion and antiskyrmion states are energetically degenerate. The latter makes these materials promising for skyrmion-based quantum computation, in which skyrmions of different topological charges play the role of qubits.

MA 37.2 Thu 9:45 EB 301

Topological Magnon-Plasmon-Polaritons in Ferromagnets, Antiferromagnets and Skyrmion Crystals — Tomoki Hirosawa[1], Pieter Gunnink[2], and •Alexander Mook[2] — [1]Aoyama Gakuin University, Japan — [2]Johannes Gutenberg University Mainz

The strong coupling of magnetic excitations with electromagnetic waves and other collective modes in the solid state offers exciting possibilities for magnonic quantum hybrid systems and cavity control of material properties. The recent advent of two-dimensional materials has sparked interest in the hybridization of magnons with plasmons [1-3], which can support topologically non-trivial properties [4,5].

Here, we explore the topological properties of magnon(-plasmon) polaritons with a strong focus on effectively two-dimensional ferromagnets, antiferromagnets, and skyrmion crystals. We show that the anticrossing can give rise to a finite quasiparticle Berry curvature and a topological gap. We discuss the possibility of chiral edge states and cavity-engineered thermal Hall and spin Nernst transport.

[1] Ghosh et al., Phys. Rev. B 107, 195302 (2023), [2] Dyrdał et al., Phys. Rev. B 108, 045414 (2023), [3] Costa et al., Nano Lett. 23, 10, 4510-4515 (2023), [4] Okamoto et al., Phys. Rev. B 102, 064419 (2020), [5] Efimkin, Kargarian, Phys. Rev. B 104, 075413 (2021),

MA 37.3 Thu 10:00 EB 301

Laser-Controlled Real- and Reciprocal-Space Topology in Multiferroic Insulators — Tomoki Hirosawa[3], Jelena Klinovaja[2], Daniel Loss[2], and •Sebastián A. Díaz[1] — [1]University of Konstanz, Konstanz, Germany — [2]Univesity of Basel, Basel, Switzerland — [3]Aoyama Gakuin University, Tokyo, Japan

Magnetic materials in which it is possible to control the topology of their magnetic order in real space or the topology of their magnetic excitations in reciprocal space are highly sought-after as platforms for alternative data storage and computing architectures. Here we show that multiferroic insulators, owing to their magneto-electric coupling, offer a natural and advantageous way to address these two different topologies using laser fields. We demonstrate that via a delicate balance between the energy injection from a high-frequency laser and dissipation, single skyrmions—archetypical topological magnetic textures—can be set into motion with a velocity and propagation direction that can be tuned respectively by the laser field amplitude and polarization. Moreover, we uncover an ultrafast Floquet magnonic topological phase transition in a laser-driven skyrmion crystal and we propose a new diagnostic tool to reveal it using the magnonic thermal Hall conductivity.

[1] T. Hirosawa, J. Klinovaja, D. Loss, and S. A. Díaz, Phys. Rev. Lett. 128, 037201 (2022)

MA 37.4 Thu 10:15 EB 301

Intrinsic and extrinsic skyrmion Hall deflections of intrinsic AFM skyrmions — •Amal aldarawsheh[1,2], Moritz Salermann[1,3,4], Muayad Abusaa[5], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulations, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [3]RWTH Aachen University, 52056 Aachen, Germany — [4]Science Institute and Faculty of Physical Sciences, University of Iceland, VR-III, 107 Reykjavík, Iceland — [5]Arab American University, Jenin, Palestine

Antiferromagnetic (AFM) skyrmions, comprised of two antiferromagnetically coupled ferromagnetic (FM) solitons, are promising for spintronic racetrack memories due to their predicted zero skyrmion Hall effect. Our ab-initio study explores the dynamic behavior of intrinsic single and interchained AFM skyrmions in the CrPdFe/Ir(111) system [1,2] driven by a spin torque, all based on atomistic spin dynamics simulations. Surprisingly, we unveil an intrinsic and extrinsic skyrmion Hall and uncover that FM skyrmions in the underlying Fe layer act as effective traps for AFM skyrmions, confining and reducing their velocity. These findings hold significant promise for spintronic applications, advancing our understanding of AFM and FM skyrmion interactions in heterostructures. [1] A. Aldarawsheh et al., Nat. Commun.**13**, 7369 (2022). [2] A. Aldarawsheh et al., Front. Physics. **11**, 335 (2023). Work funded by the PGSB (BMBF-01DH16027)and DFG (SPP 2137; LO 1659/8-1)

MA 37.5 Thu 10:30 EB 301

Dipolar-stabilized skyrmions transparent for TEM — •Andrii Savchenko[1], Vladyslav Kuchkin[2], Filipp Rybakov[3], and Nikolai Kiselev[1] — [1]Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Science Institute, University of Iceland, 101 Reykjavík, Iceland — [3]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden

In magnetic multilayers with asymmetric interfaces between magnetic and nonmagnetic layers, the interfacial Dzyaloshinskii-Moriya interaction (iDMI) can give rise to dipolar-stabilized skyrmions (magnetic bubbles) with Neel-type domain walls (DWs). For these DWs, the Lorentz Transmission Electron Microscopy (LTEM) contrast is absent when the electron beam is incident normal to the film surface and occurs only when the sample is tilted with respect to the beam. Such behavior in LTEM is often used to confirm the presence of iDMI. We have found another type of DW that exhibits the same behavior in LTEM. These Bloch-type DWs possess alternating chirality in adjacent layers. The skyrmions with these DWs can be observed in multilayers with weak interlayer exchange coupling (IEC) and without iDMI. The LTEM contrast for these skyrmions becomes visible only when the sample is tilted relative to the electron beam. In multilayers without IEC, dipolar skyrmions with alternating chirality and fixed chirality in the DWs have nearly identical energies and can coexist in the whole range of magnetic fields. Thus, the binary data can be efficiently encoded by the sequence of skyrmions of those two types.

MA 37.6 Thu 10:45 EB 301

Multipole magnons in topological skyrmion lattices resolved by cryogenic Brillouin light scattering microscopy — •Riccardo Ciola[1], Ping Che[2], Markus Garst[1], Volodymyr Kravchuk[1], Arnaud Magrez[2], Helmuth Berger[2], Thomas Schönenberger[2], Henrik Rønnow[2], and Dirk Grundler[2] — [1]Karlsruhe Institute of Technology, Germany — [2]École Polytechnique Fédérale de Lausanne, Switzerland

Chiral magnets provide an innovative framework to study non-collinear spin textures and their associated magnetization dynamics. They include helical and conical magnetic textures that are spatially modulated with a wavevector k_h as well as the topologically non-trivial skyrmion lattice (SkL) phase. Their spin waves have been explored in the long-wavelength regime using resonance and spin wave spectroscopy, and in the short wavelength regime using inelastic neutron scattering. Here, we show that Brillouin light scattering (BLS) is ideally suited to probe the complementary range of wavevectors $k \leq k_h$. We analysed bulk spin waves in the SkL phase of Cu_2OSeO_3. We provide parameter-free predictions for the corresponding resonances and their spectral weights. The theoretical results are compared to a BLS experiment in the backscattering geometry that probe magnons with a wavevector $k = 48 rad/\mu m < k_h = 105 rad/\mu m$. The clockwise, counterclockwise and breathing modes are resolved. Due to the finite wavevector of the magnon excitations, finite spectral weight is theoretically predicted also for other resonances. Experimentally, at least one additional resonance with quadrupole character is identified.

MA 37.7 Thu 11:00 EB 301

Skyrmion lattice and helical spin waves in the B20 chiral magnet $Cr_{0.82}Mn_{0.18}Ge$ — •Victor Ukleev[1], Priyaranjan Baral[2], Jonathan White[2], Chen Luo[1], Florin Radu[1], and Luana Caron[1,3] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Paul Scherrer Institute, Villigen, Switzerland — [3]Faculty of Physics, Bielefeld University, Bielefeld, Germany

In our comprehensive investigation, we delve into the intriguing magnetic properties of the solid solution $Cr_{0.82}Mn_{0.18}Ge$, which emerges from the chiral cubic B20-type compounds CrGe and MnGe. While CrGe remains a metallic paramagnet devoid of long-range magnetic order, MnGe is a helimagnet with a short spiral pitch of a few nm. Our study reveals a striking difference from the behaviors of the parent compounds and $Cr_{0.82}Mn_{0.18}Ge$. Bulk measurements, coupled with small-angle neutron scattering, unambiguously establish the helimagnetic ground state below the critical temperature (T_C) of 13 K, wherein the spiral pitch undergoes a notable variation from 40 to 35 nm upon cooling to 2 K. We identify a low-field induced skyrmion state in the A-phase, extending over an unusually wide temperature range, 6 K below T_C. Remarkably, these field-cooled skyrmions persist as a metastable state at the base temperature and zero field, demonstrating the unique and robust nature of this magnetic configuration. This study not only contributes to the understanding of the magnetic phase diagram of $Cr_{0.82}Mn_{0.18}Ge$ but also highlights the emergence and stability of exotic magnetic states in this solid solution, paving the way for further exploration of its unique magnetic properties.

15 min. break

MA 37.8 Thu 11:30 EB 301

Nonlinear dynamics and stability of skyrmion strings — •Volodymyr Kravchuk — Leibniz Institute for Solid State and Materials Research, , Helmholtzstraße 20, 01069 Dresden

Here we analyze the nonlinear dynamics of a skyrmion string in a low-energy regime by means of the collective variables approach. Using the perturbative method of multiple scales (both in space and time), we show that the weakly nonlinear dynamics of the translational mode propagating along the string is captured by the focusing-type nonlinear Schroedinger equation [1]. As a result, the basic planar-wave solution, which has the form of a helix-shaped wave, experiences modulational instability. The latter leads to the formation of cnoidal waves. Both types of cnoidal waves, dn- and cn-waves, as well as the separatrix soliton solution, are confirmed by micromagnetic simulations. Beyond the class of traveling-wave solutions, we found Ma-breather propagating along the string. Finally, we proposed a generalized approach that enables one to describe the nonlinear dynamics of the modes of different symmetries, e.g., radially symmetrical or elliptical.

By computing the spectrum of the magnons propagating along the string in the presence of the longitudinal spin current, we found the current-induced Goldstone spin wave instability. A longitudinal current is thus able to melt the skyrmion string lattice via a nonequilibrium phase transition [2].

[1] V.P. Kravchuk, Phys. Rev. B 108, 144412 (2023).

[2] S. Okumura, V.P. Kravchuk, M. Garst, Phys. Rev. Lett. 131, 066702 (2023).

MA 37.9 Thu 11:45 EB 301

Unravelling the significance of higher-order exchange interactions for skyrmion stability in monolayer MnSeTe — •Megha Arya[1], Lionel Calmels[1], Rémi Arras[1], Soumyajyoti Haldar[2], Stefan Heinze[2], and Dongzhe Li[1] — [1]CEMES, Université de Toulouse, CNRS, 29 rue Jeanne Marvig, F-31055 Toulouse, France — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstrasse 15, 24098 Kiel, Germany

Magnetic skyrmions in atomically thin van der Waals (vdW) materials provide an ideal playground to push skyrmion technology to the single-layer limit. Here, we investigate the intrinsic magnetic skyrmions in a monolayer Janus vdW magnet, MnSeTe, by first-principles calculations combined with atomistic spin simulations. A very large Dzyaloshinskii-Moriya interaction (DMI) is observed due to the intrinsic broken inversion symmetry and strong spin-orbit coupling for monolayer MnSeTe, which is in agreement with the literature. We will show that the interplay between the large DMI, the exchange coupling, and the magnetic anisotropy energy allows stabilizing zero-field nanoscale skyrmions in monolayer MnSeTe, becoming technologically competitive. We further show that the nanoscale skyrmions have moderate energy barriers protecting skyrmions against annihilation. Finally, we unravel the role of higher-order exchange interactions - which have so far been overlooked - as they can play an intriguing role in the stability of skyrmions.

MA 37.10 Thu 12:00 EB 301

Enhanced thermally-activated skyrmion diffusion with tuneable effective gyro tropic force — Takkaki Dohi[1], Markus Weissenhofer[2], Nico Kerber[1], Fabian Kammerbauer[1], Yuqing Ge[1], •Klaus Raab[1], Jakub Zázvorka[3], Maria-Andromachi Syskaki[1,4], Aga Shahee[1], Moritz Ruhwedel[5], Tobias Böttcher[5], Philip Pirro[5], Gerhard Jakob[1], Ulrich Nowak[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Fachbereich Physik, Universität Konstanz, DE-78457 Konstanz, Germany — [3]Institute of Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, Prague 12116, Czech Republic — [4]Singulus Technologies AG, 63796 Kahl am Main, Germany — [5]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Gottlieb-Daimler-Straße 46, 67663 Kaiserslautern, Germany

The topology of magnetic skyrmions lets them respond distinctly to electromagnetic stimuli and should have a substantial effect on stochastic diffusive motion. We present enhanced thermally activated diffusive motion of skyrmions within a specially designed synthetic antiferromagnet1, in which the topology can be precisely tuned2. By suppressing the effective topological charge, we achieve a diffusion coefficient more than ten times higher compared to ferromagnetic skyrmions and demonstrate the topology-dependence of the diffusive dynamics. 1.*Dohi, T. et al. Nat. Commun. 10, 5153 (2019). 2.*Dohi, T. et al. Nat. Commun. 14 (2023).

MA 37.11 Thu 12:15 EB 301

Enhancing Skyrmion Diffusion by Alternating Excitations — •Maarten A. Brems, Raphael Gruber, Tobias Sparmann, Jan Rothörl, Peter Virnau, and Mathias Kläui — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Magnetic skyrmions in thin films have been shown to exhibit thermal diffusion in a pinning-induced inhomogeneous energy landscape [1]. As a consequence, the targeted manipulation of the skyrmions' interaction with the pinning sites allows us to drastically enhance skyrmion diffusivity even at constant temperature. Recently, we have experimentally demonstrated an increase of the skyrmion diffusion coefficient by over two orders of magnitude [2]. Therein, we leverage the systems' intrinsic stochasticity directly as we employ fully deterministic excitations only. Constant-temperature tunability of stochastic motion is key to dynamically adjusting the speed-efficiency-balance of skyrmion-based Brownian computers [3] and thereby greatly enhances their application scenarios [4].

[1] R. Gruber et al., Nat Commun 13, 3144 (2022). [2] R. Gruber, M. A. Brems et al., Adv. Mater. 35, 2208922 (2023). [3] K. Raab, M. A. Brems et al., Nat. Commun. 13, 6982 (2022). [4] M. A. Brems et al., Appl. Phys. Lett. 119, 132405 (2021).

MA 37.12 Thu 12:30 EB 301

Simulation of a realistic skyrmion-based multiturn counter-sensor device at finite temperatures — •Kilian Leutner[1], Thomas Brian Winkler[1], Robert Frömter[1], Raphael Gruber[1], Johannes Güttinger[2], Hans Fangohr[3], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Infineon Technologies AG, Villach, Austria — [3]Max-Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany

Magnetic skyrmions, as topologically stabilized quasi particles, hold great promise for energy-efficient applications encompassing storage, logic, and sensing devices. In this work, we introduce an innovative, realistic, and feasible concept for a multi-turn counter-sensor device utilizing skyrmions, a step towards applied skyrmionics. In the sensor the encoded number of sensed rotations corresponds to the number of nucleated skyrmions [1]. The sensor only consumes energy at the readout. Our simulation study reveals a robust design and protocol for reading out a skyrmion storage, facilitating accurate quantification of skyrmion numbers, even in the presence of thermal fluctuations and thermal diffusion. Emphasizing the fundamental principles underlying reliable and realistic readout mechanisms, our findings extend applicability to a broader class of skyrmion-based devices. Additionally, we provide insights into the detection of skyrmions through their strayfield via magnetic tunnel junctions (MTJ).

[1] K. Leutner, et al., Phys. Rev. Appl., accepted (2023), arXiv:2211.05711 (2022)

MA 37.13 Thu 12:45 EB 301

Antiferromagnetic (anti)merons and bimerons in synthetic antiferromagnets — •Mona Bhukta[1], Takaaki Dohi[1,2], Venkata Krishna Bharadwaj[1], Ricardo Zarzuela[1], Maria-Andromachi Syskaki[1], Jairo Sinova[1], Robert Frömter[1], and Mona Bhukta[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, 2-1-1 Katahira, Aoba, Sendai 980-8577, Japan

In recent years, topological defects stabilized by the Dzyaloshinskii-Moriya interaction, such as skyrmions, bimerons, etc, have caught increasing interest due to their small size, topologically enhanced stability and low threshold-current density required for their motion under the application of spin-orbit torques [1]. In this work, we investigate the conditions to stabilize antiferromagnetic meronic spin textures at room temperature to observe them experimentally in synthetic antiferromagnets [2]. By combining different magnetic imaging techniques such as magnetic force microscopy (MFM), scanning electron microscopy with polarization analysis (SEMPA), and X-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM) we image the three-dimensional Néel order parameter, revealing the of merons and antimerons in the Pt/CoFeB/Ir based SyAFM stacks [3].

[1] K. Litzius et al., Nat. Phys. 13, 170 (2017) [2] T. Dohi et al, Nat. Commun. 10, 5153 (2019) [3] M. Bhukta et al, arXiv:2303.14853 (2023)

MA 38: Ultrafast Magnetization Effects III

Time: Thursday 11:15–12:45 Location: EB 202

MA 38.1 Thu 11:15 EB 202

Ultrafast changes in the M_5/M_4 branching ratio in Terbium — •Tim Amrhein[1], Beyza Salantur[1], Niko Pontius[2], Christian Schuessler-Langeheine[2], Martin Weinelt[1], and Nele Thielemann-Kühn[1] — [1]Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Str. 15, 12489 Berlin, Germany

As reported recently, inelastic $5d$-$4f$ electronic scattering in $4f$ rare earth metals transiently alters the $4f$ orbital state and therewith the total angular momentum J [1]. These transitions change the electronic and magnetic properties in $4f$ metals on ultrafast time scales. Within an X-ray absorption study performed at the FemtoSpeX slicing facility at BESSY II we show, that the observed changes of J also affect the M_5/M_4 branching ratio on ultrafast timescales in Terbium, proving the 3rd rule of Thole and Van der Laan [2] to be applicable in non-equilibrium. The change of the branching ratio can be used, to calculate the percentage of $4f$-excited atoms.

[1] N. Thielemann-Kühn et al., *Optical control of $4f$ orbital state in rare-earth metals.* https://doi.org/10.48550/arXiv.2106.09999 (Science Advances, in revision)

[2] B. T. Thole and G. van der Laan., *Branching ratio in x-ray absorption spectroscopy.* Phys. Rev. B, 38:3158-3171, Aug 1988.

MA 38.2 Thu 11:30 EB 202

Picosecond X-ray magnetic circular dichroism with a laser-driven plasma source — •Konstanze Korell, Martin Borchert, Leonid Lunin, Daniel Schick, and Stefan Eisebitt — Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Max-Born-Straße 2A, 12489 Berlin

X-ray magnetic circular dichroism (XMCD) combines large magnetic contrast with element-selectivity, and access to buried layers. In the soft-X-ray range at the 3d transition metal L and rare earth M edge (500-1500 eV), so-called sum-rules even allow to disentangle the spin and orbital angular momentum. However, XMCD spectroscopy requires soft X-rays with circular polarization, limiting this powerful technique to accelerator-based large-scale facilities such as synchrotrons and free-electron lasers. Recently, we have demonstrated the first laboratory-based XMCD experiment at the Fe L-edges outside of large-scale facilities using laser-driven plasma X-ray source (PXS) in combination with a ferrimagnetic polarizer to generate partially circular polarization. In this contribution, I will present the design and specifications of our new beamline dedicated for time-resolved XMCD spectroscopy. The setup features an extremely broad spectral range from 50-1500 eV with a 40 μm (FWHM) X-ray focus and sub-10 ps temporal resolution. Further, I will present and discuss first results towards time-resolved XMCD spectroscopy on a FeGd multilayer sample after photoexcitation.

MA 38.3 Thu 11:45 EB 202

Magneto-thermal engineering of the fast magnetic response to ultrashort laser excitation of 2D-van der Waals heterostructures — •Theodor Griepe[1], Sumit Haldar[2], Unai Atxitia[1], and Elton Santos[2] — [1]CSIC Insituto de Ciencia de Materiales de Madrid — [2]University of Edinburgh

Two-dimensional van der Waals ferromagnets, such as Cr2Ge2Te6 and Fe3GeTe2, have gathered an increasing interest over the past years. As for example, their ultrafast magnetic response to femtosecond optical excitation. For practical applications, full control of magnetization dynamics time scales up to several nanoseconds is an paramount for the design of magnetic devices with high high access rate. In this work, we conduct a numerical investigation of both thermal and magnetic response of 2D van der Waals heterostructures, composed of a ferromagnetic layers sandwiched between two insulating cap and substrate layers. Our model shows that the picosecond magnetic response is governed by strong out-of-equilibrium interactions between the subsystems of electrons, phonons and spins. We use an enhanced microscopic three temperature model to show how the picosecond magnetic response is governed by strong out-of-equilibrium interactions between the subsystems of electrons, phonons and spins. For longer time scales, the magnetic response can be controlled by the thermodynamic properties of the heterostructure owing to the distinct heat transport and interfacial conductivity of the constituents.

MA 38.4 Thu 12:00 EB 202

Nonlinearities in ultrafast transverse magneto-optical Kerr effect spectroscopy — •Johanna Richter, Somnath Jana, Ole Zülich, Daniel Schick, Clemens von Korff-Schmising, and Stefan Eisebitt — Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy

Ultrafast magneto-optical Kerr effect spectroscopy (T-MOKE) in the extreme ultraviolet spectral range provides detailed insight into element-specific magnetization dynamics and has become a powerful experimental technique for unravelling the fundamental microscopic processes occurring in laser-excited magnetic materials.

In this work, we investigate the relationship between the T-MOKE observable (magnetic asymmetry) and the element-specific magnetization by calculating the exact response based on a wave propagation algorithm. We present detailed simulations for realistic magnetic multilayers as a function of incident angle and photon energies between 40 eV and 72 eV and find pronounced deviations in the proportionality between magnetization and asymmetry. These findings reproduce time-resolved measurements exhibiting strong nonlinearities, including situations where the asymmetry increases despite of a decreasing magnetization. We introduce a metric to quantify these nonlinearities and identify sample structures and T-MOKE geometries where a direct proportionality between T-MOKE measurements and magnetization remains a good approximation, and show how our data methodology allows a correct interpretation of T-MOKE experiments.

MA 38.5 Thu 12:15 EB 202

Coherent control of nuclear excitons in FeRh — •Sakshath

Sadashivaiah[1,2], Kai Schlage[3], Anjali Panchwanee[3], Christina Bömer[3], Dietrich Krebs[3], Berit Marx-Glowna[1,2], Robert Lötzsch[4], Lars Bocklage[3], Olaf Leupold[3], Ilya Sergueev[3], and Ralf Röhlsberger[1,2,3,4] — [1]Helmholtz-Institut Jena, Fröbelstieg 3, 07743 Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Deutsches Elektronen Synchrotron, Notkestraße 85, 22607 Hamburg, Germany — [4]Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

The narrow linewidth of Mössbauer resonances (4.5 neV in ^{57}Fe) enables the preparation of well-defined nuclear quantum states, whose energies are addressed by accelerator-driven light sources [1,2]. Laser-induced phase transitions can modify these nuclear excitonic states via the hyperfine interactions [3]. In ^{57}FeRh thin films femtosecond laser pulses cause an isostructural antiferromagnet (AFM) - ferromagnet (FM) phase transition. Simultaneously, the coherence of the nuclear resonant forward scattered photons is changed within 500 ps. By characterizing the (002) diffraction peak of ^{57}FeRh, we demonstrate that the laser pulses can coherently steer the resonant photons from along the AFM phase to the direction corresponding to the FM phase. Thus, we strive to open new pathways for the coherent control of nuclear excitonic states. [1] R. Röhlsberger et al., Science 328, (2010) 1248. [2] K. P. Heeg et al., Nature 590, (2021) 401. [3] S. Sadashivaiah et al., J. Phys. Chem. Lett. 12, (2021) 3240.

MA 38.6 Thu 12:30 EB 202

Ultrafast Magnetization Dynamics of Nanoscale Domains in Ferrimagnetic DyCo Films Studied at European XFEL — •Simon Marotzke[1,2], André Philippi-Kobs[1], Dieter Lott[3], Matthias Riepp[4], Leonard Müller[1], Robert Frömter[5], Loic Le Guyader[6], Andreas Scherz[6], Florin Radu[7], Gerhard Grübel[1,6], Martin Beye[1,8], and Kai Rossnagel[1,2] — [1]DESY, Hamburg, Germany — [2]CAU Kiel, Germany — [3]Helmholtz-Zentrum Hereon, Geesthacht, Germany — [4]Université de Strasbourg, France — [5]JGU Mainz, Germany — [6]European XFEL, Schenefeld, Germany — [7]HZB, Berlin, Germany — [8]Stockholm University, Sweden

Ferrimagnetic DyCo$_x$ is a fascinating magnetic composition for both fundamental as well as applied studies on magnetism due to the easy tunability of its magnetic state by temperature and composition. While the global behavior of its magnetization dynamics upon ultrashort laser excitation has been studied, the response of its nanoscale magnetic domain state is completely unknown. Here, in particular, it is of high interest if super-diffusive currents of highly excited electrons lead to modifications of the domain structure that may be different for both Dy and Co sublattices, resulting in the creation of a transient non-collinear state within the domain walls. We addressed the ultrafast response of the nanoscale domain state by performing magnetic small-angle X-ray scattering experiments on ultrathin DyCo$_3$ films at the Spectroscopy and Coherent Scattering (SCS) instrument of the European XFEL. We report on first results indicating the existence of a transient non-colinear magnetic state.

MA 39: SrTiO$_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor II (joint session TT/KFM/MA/O)

Strontium titanate (SrTiO$_3$) is a paradigmatic material that plays an important role in various fields of solid-state physics, surface science and catalysis: The pure bulk phase is a wide-band-gap semiconductor that upon cooling becomes a textbook quantum paraelectric. When slightly doped, SrTiO$_3$ turns into a Fermi-liquid-type metal that becomes superconducting at extremely low charge carrier density. SrTiO$_3$-based surfaces and interfaces host un-conventional electronic states such as quasi-two-dimensional electron liquid, magnetism and superconductivity. Despite intensive studies over the past decades, SrTiO$_3$ continues to reveal surprising new phenomena that challenge the established views on this material. To this end achieving light-induced nonequilibrium states and the recent preparation of a 2D oxide based on SrTiO$_3$ opens new playgrounds for research. This Focus Session will present exciting developments in the study of electronic states that are based on the peculiar properties of SrTiO$_3$.

Please note that this Focus Session comprises four parts: Posters are presented within the TT poster session TT58 (Wed 15:00-18:00, poster area E). Invited talks are compiled in the session TT62 (Thursday, 9:30 to 12:45, H0104), Contributed talks will be presented in sessions TT72 (Thursday 15:00-18:00, H0104) and TT83 (Fri 9:30-12:30, H0104).

Organizers: Rossitza Pentcheva, University of Duisburg-Essen, Marc Scheffler, University of Stuttgart

Time: Thursday 15:00–18:00 Location: H 0104

MA 39.1 Thu 15:00 H 0104

Origin of unconventional normal-state transport and superconductivity in electron-doped SrTiO$_3$ — •Stephen Rowley — Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge, CB3 0HE, United Kingdom

Quantum phase transitions may be reached in many ferroelectric systems by supressing the Curie temperature to absolute zero using a control parameter such as chemical substitution or hydrostatic pressure. In electron-doped specimens of quantum critical ferroelectrics such as SrTiO$_3$, unconventional superconductivity and unusual normal-state transport have been detected. In the latter case, a resistivity varying as temperature-squared is observed over a wide range of temperatures above the Fermi temperature. We present new experimental and model results that provide insight into the nature of the mechanisms for both superconductivity and normal-sate transport. We find in experiments and quantitative models without adjustable parameters, that both effects are connected and enhanced in samples tuned to the ferroelectric quantum critical point. Superconductivity appears to arise near the critical point due to the virtual exchange of longitudinal hybrid-polar-modes, even in the absence of a direct coupling to the transverse-optical phonon modes.

MA 39.2 Thu 15:15 H 0104

Dilute superconductivity in the vicinity of a ferroelectric quantum critical point coupled via the "vector coupling": The case of SrTiO$_3$ — •Sudip Kumar Saha[1,2], Avraham Klein[1], Jonathan Ruhman[2], and Maria Navarro Gastiasoro[3] — [1]Ariel University, Israel — [2]Bar-Ilan University, Israel — [3]Donostia International Physics Center, Spain

Lightly doped SrTiO$_3$ (STO) is one of the most studied examples of quantum ferroelectric metal (QFEMs), where superconductivity coexists with ferroelectric order. Pristine STO is paraelectric naturally close to a ferroelectric quantum critical point (QCP). Strain or chemical substitution (for example, doping with Ba/Ca instead of Sr) drives STO through the QCP to the ferroelectric phase, which manifests itself in the softening of the transverse optical (TO) phonon mode. Doped samples are superconducting, where the T_c vs. density dome extends to very low density. To date, there is no consensus on the mechanism leading to superconductivity at such low density. Edge et al. have proposed that the ferroelectric QCP and dilute superconductivity are related [Phys. Rev. Lett. 115, 247002 (2015)]. In this work we explore the possible origin of low-density superconductivity from coupling linearly to the TO mode via a "vector coupling". We solve the critical-Eliashberg theory numerically, including fermionic and bosonic self-energy corrections, which allows us access all the way to the QCP. Notably, all our calculations are justified within standard approaches. We find the existence of a superconducting dome with magnitude and dependence on the distance from the QCP that resembles experiments.

MA 39.3 Thu 15:30 H 0104

Dislocation-based filamentary superconductivity in reduced $SrTiO_3$ — •Christian Rodenbücher[1], Gustav Bihlmayer[2], Carsten Korte[1], and Kristof Szot[3] — [1]Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK-14), 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institut (PGI-1), 52425 Jülich, Germany — [3]University of Silesia, Institute of Physics, 41-500 Chorzów, Poland

Exposure of $SrTiO_3$ single crystals to reducing conditions at elevated temperatures leads to the generation of metallic filaments forming along of dislocations, which act as preferential reduction sites. This effect can be enhanced when stimulating the local deoxidation by electric fields. This results in an agglomeration of metallic filaments in nano-bundles, which are embedded in the insulating surrounding crystal matrix. Despite removing only 10^{14-15} oxygen atoms from the dislocation network, electro-reduced crystals are superconducting with a transition temperature of 0.2 K, and their residual resistance is lower than that of purely thermally-reduced crystals. As the total amount of oxygen removed during electro-reduction is much smaller than the smallest reported carrier concentration for superconducting $SrTiO_{3-x}$ so far, our findings challenge traditional explanations of superconductivity in metal oxides. Combining conductivity characterization by atomic force microscopy with theoretical analysis of the dislocation cores, we propose a model explaining the superconducting properties by the coexistence of metallic dislocation cores with polar insulating regions allowing for polaronic coupling in the bundles.

MA 39.4 Thu 15:45 H 0104

Dislocation-Induced Photoconductivity Enhancement in Fe-Doped $SrTiO_3$: compensation of low mobility by high carrier density through the emergence of a sub-band gap level — •mehrzad soleimany[1,2], till frömling[1], jürgen rödel[1], and marin alexe[2] — [1]Department of Materials and Earth Sciences, Technical University of Darmstadt, Darmstadt, Germany — [2]Department of Physics, University of Warwick, Coventry, UK

Owing to the remarkable properties of $SrTiO_3$ (STO), such as quantum paraelectric state below 37 K, negative differential resistance under illumination, and significant alteration of properties by doping, STO stands out among perovskite oxides. Until recently, little attention had been paid to the tunability of its properties - especially optical properties -via the introduction of dislocations. In this study, we introduce the method of dislocation imprint, which allows us to induce high densities of dislocations ($> 1 \times 10^{14}$ m^{-2}) into a large volume of Fe-doped STO. Low-temperature I-V measurements indicated an about one order of magnitude increase in the photoconductivity of dislocation-rich samples. Photo-Hall measurements revealed that while dislocations might decrease the mobility, they could enhance the photoconductivity by increasing the number of carriers. Spectral responsivity measurements demonstrated that the higher carrier density could stem from the emergence of a sub-band gap level. Complementary C-AFM measurements conducted under illumination confirmed the local enhancement of photoconductivity at dislocations, which fitted well to the Electron Channeling Contrast Images of dislocations.

MA 39.5 Thu 16:00 H 0104

IR and THz studies on $(Ba_{0.45}Sr_{0.55}TiO_3)_{24}Ba_{0.45}Sr_{0.55}O$ and $(Ba_{0.45}Sr_{0.55}TiO_3)_8Ba_{0.45}Sr_{0.55}O$ thin films — Veronica Goian[1], Matthew Barone[2], Natalie Dawley[2], Christelle Kadlec[1], •Darrell Schlom[2,3], and Stanislav Kamba[1] — [1]Institute of Physics ASCR, Prague, Czech Republic — [2]Department of Materials Science and Engineering, Cornell University, Ithaca, NY, USA — [3]Kavli Institute at Cornell for Nanoscale Science, Ithaca, NY, USA

$(SrTiO_3)_nSrO$ and (n=1..6) films crystallizing in the Ruddlesdden-Popper (RP) structure are well known for low dielectric loss and large microwave permittivities which are highly tunable with electric field.[1,2] Bulk $(SrTiO_3)_nSrO$ is paraelectric, but the tensile strained thin films deposited on (110)$DyScO_3$ with n≥3, become ferroelectric at low temperatures. $(ATiO_3)_{24}AO$ and $(ATiO_3)_8AO$, A= $Ba_{0.45}Sr_{0.55}$ films deposited on (110)$DyScO_3$ exhibit no strain and yet become ferroelectric. Here we performed infrared and THz studies of phonon dynamics down to 10 K and compared it with above mentioned thin films and (Sr,Ba)TiO_3. The effect of soft mode and central mode on microwave dielectric properties and electric field tunability of permittivity will be discussed.

[1] C. H. Lee et al., Nature, 502 (2013) 532
[2] N. M. Dawley et al., Nat. Mater. 19 (2020) 176

MA 39.6 Thu 16:15 H 0104

Polar phonon behaviour in polycrystalline Bi-doped strontium titanate thin films — •Oleksandr Tkach[1], Olena Okhay[2], Dmitry Nuzhnyy[3], Jan Petzelt[3], and Paula M. Vilarinho[1] — [1]Department of Materials and Ceramic Engineering, CICECO, University of Aveiro, Aveiro, Portugal — [2]TEMA-Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, Aveiro, Portugal — [3]Institute of Physics of the Czech Academy of Sciences, Prague, Czechia

Among strontium titanate (STO) based materials, Bi-doped STO have been intensively studied as for dielectric as for resistance-switching memory and thermoelectric applications. Here, we enhance the dielectric characterisation by a lattice dynamics study of sol-gel-derived $Sr_{1-1.5x}Bi_xTiO_3$ thin films with x = 0.0053 and 0.167, deposited on Al_2O_3 substrates, using a variable-temperature far-infrared spectroscopy in a transmittance mode. Bi doping, known to induce a low-frequency dielectric relaxation in STO ceramics and films, due to off-centre dopant ion displacements generating electric dipoles, is shown to affect the polar phonon behaviour of thin films. We show that in weakly Bi-doped films, the low-frequency polar TO1 mode softens on cooling but less than in undoped STO. In heavily Bi-doped STO films, this mode displays no significant frequency variation with temperature from 300 to 10 K. The polar phonon behaviour of polycrystalline Bi-doped STO thin films is comparable with that of Bi-doped STO ceramics, which exhibit dielectric relaxations and harden soft-mode behaviour instead of the ferroelectric phase transition.

15 min. break

MA 39.7 Thu 16:45 H 0104

Emergence of strain-Induced magnetism in plastically-deformed SrTiO3 at low temperature — •Anirban Kundu[1], Xi Wang[2], Avraham Klein[1], and Beena Kalisky[2] — [1]Department of Physics, Ariel University, Israel — [2]Institute of Nanotechnology & Advanced Materials, Bar-Ilan University, Israel

It is well established that SrTiO3 (STO) can possess ferroelectric states alongside observed superconducting states. However, so far, the phenomena of magnetism have not been established. In our collaborative work, in a plastically deformed bulk STO sample; SQUID measurements reveal strong magnetic signals which are completely absent in pristine samples. This strain-induced magnetism has two salient features. First, the magnetic moment is seen only with applied strain and increases with applied strain. Second, it also increases with temperature. Using Ginzberg Landau theory we show that these properties may be the result of coupling terms between strain, polar, and magnetic orders centered around dislocation walls induced by the plastic deformation. Our analysis implies that deformed STO is a quantum multiferroic.

MA 39.8 Thu 17:00 H 0104

Mobility in $SrTiO_3$ Mediated by Machine Learning Predicted Anharmonic Phonons — •Luigi Ranalli[1], Carla Verdi[2], and Cesare Franchini[1] — [1]University of Vienna, Vienna, Austria — [2]University of Queensland: Brisbane, Queensland, Australia

The anharmonic corrections to ionic motion play a crucial role in influencing the electron-phonon interaction, a phenomenon typically addressed through harmonic dynamical matrices at the ground state. By combining machine learning methodologies [1] and the stochastic self-consistent harmonic approximation [2], we achieve a precise depiction of the temperature-dependent evolution of phonon frequencies and the onset of ferroelectricity in the quantum paraelectric perovskites $SrTiO_3$ [3] and $KTaO_3$ [4]. In this presentation, anharmonic dynamical matrices are incorporated into the Boltzmann transport equation calculations for $SrTiO_3$ up to 300K using the EPW code [5] and fixing the derivatives of the Kohn-Sham potential computed through density functional perturbation theory [6]. This approach yields a coherent interaction vertex, ensuring that the temperature-dependent ferroelectric soft mode explains and recovers the observed trend in experimental mobility, akin to the behavior observed in $KTaO_3$.

[1] R. Jinnouchi et al., Phys. Rev. Lett. 122 (2019) 225701
[2] L. Monacelli et al., J. Phys.: Condens. Matter 33 (2021) 363001
[3] C. Verdi et al., Phys. Rev. Materials 7 (2023) L030801
[4] L. Ranalli et al., Adv. Quantum Technol. 6 (2023) 2200131
[5] H. Lee et al., 10.1038/s41578-021-00289-w (2023)
[6] J. Zhou et al., Phys. Rev. Research 1 (2019) 033138

MA 39.9 Thu 17:15 H 0104

Machine-learning-backed evolutionary exploration of the $SrTiO_3$(110) surface phase diagram — •Ralf Wanzenböck[1], Florian Buchner[1], Michele Riva[2], Jesús Carrete[3,1], and Georg K. H. Madsen[1] — [1]Institute of Materials Chemistry, TU Wien, A-1060 Vienna, Austria — [2]Institute of Applied Physics, TU Wien, A-1040 Vienna, Austria — [3]Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza, 50009 Zaragoza, Spain

We use Clinamen2, a modern functional-style Python implementation of the covariance matrix adaptation evolution strategy (CMA-ES), to gain insights into the lesser-known regions of the complex $SrTiO_3$(110) surface phase diagram. To speed up the process, we leverage the transferability of a neural-network force field (NNFF) implemented on top of the state-of-the-art JAX framework.

Starting from smaller reconstructions in well-explored phases, such as the 4×1 surface reconstruction [Wanzenböck et al., Digit Discov 1, 703-710 (2022)], the NNFF is iteratively refined using an active learning workflow that relies on uncertainty estimation techniques [Carrete et al., J. Chem. Phys 158, 204801 (2023)]. We show how this workflow and the underlying uncertainty metric lead to a flexible NNFF, highlighted by the exploration of out-of-sample $SrTiO_3$(110)-($2 \times n$) reconstructions.

MA 39.10 Thu 17:30 H 0104

Quasiparticle and excitonic properties of monolayer $SrTiO_3$ — •Lorenzo Varrassi[1], Peitao Liu[2], and Cesare Franchini[1,3] — [1]Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna — [2]Shenyang National Laboratory for Materials Science, Institute of Metal Research — [3]University of Vienna, Faculty of Physics and Center for Computational Materials Science, Vienna.

Recently, a breakthrough has been achieved with the synthesis of free-standing $SrTiO_3$ ultrathin films down to the monolayer limit[1]; its optical and excitonic properties remain however largely unexplored. This talk will provide insights on the quasiparticle and excitonic properties of monolayer $SrTiO_3$, employing many-body perturbation theory.

Our analysis[2] emphasizes the need to go beyond the diagonal GW approximation and include off-diagonal self-energy elements in order to obtain correct description of the orbital hybridizations. A fully satisfying description is achieved by treating non-locality in both exchange and correlation.

The optical properties are studied through the solution of the Bethe-Salpeter equation. We observe a significant enhancement of the excitonic effects with respect to the bulk phase, with a binding energy at the optical gap about four times greater. Furthermore, the two-dimensional polarizability at the long wavelength limit is dominated by two strongly bound excitonic peaks; their character is determined through the analysis of the excitonic wavefunctions.

[1] D. Ji et al., Nature 570 (2019) 87
[2] L. Varrassi et al., arxive:2303.14830 (2023)

MA 39.11 Thu 17:45 H 0104

$SrTiO_3$: Thoroughly investigated but still good for surprises — •Annette Bussmann-Holder[1], Reinhard K. Kremer[1], Krystian Roleder[2], and Ekhard K. H. Salje[3] — [1]Max-Planck-Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]Institute of Physics, University of Silesia, ul. 75 Pułku Piechoty 1, 41-500 Chorzów, Poland — [3]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, United Kingdom

For decades $SrTiO_3$ is in the focus of research with seemingly never-ending new insights regarding its ground state properties, its application potentials, its surface and interface properties, the superconducting state, the twin boundaries and domain functionalities, etc. Here, we focus on the already well-investigated lattice dynamics of STO and show that four different temperature regimes can be identified which dominate the elastic properties, the thermal conductivity and the birefringence. These regimes are the low-temperature quantum fluctuation dominated one, followed by an intermediate regime, the region of the structural phase transition at 105 K and its vicinity, and at high temperatures a regime characterized by precursor and saturation effects. They can all be elucidated by lattice dynamical aspects. The relevant temperature dependencies of the soft modes are discussed and their relationship to lattice polarizability is emphasized.

MA 40: Frustrated Magnets II

Time: Thursday 15:00–17:45 Location: H 1058

MA 40.1 Thu 15:00 H 1058

Emergent chiral metal near a Kondo breakdown quantum phase transition — •Tom Drechsler and Matthias Vojta — Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

The destruction of the Kondo effect in a local-moment metal can lead to a topological non-Fermi-liquid phase, dubbed fractionalized Fermi liquid, with spinon-type excitations and an emergent gauge field. If the latter displays an internal π-flux structure, a chiral heavy-fermion metal naturally emerges near the Kondo-breakdown transition.

Utilizing a parton mean-field theory describing the transition between a conventional heavy Fermi liquid and a U(1) fractionalized Fermi liquid, we find a novel intermediate phase near the transition whose emergent flux pattern spontaneously breaks both translation and time-reversal symmetries. This phase is an orbital antiferromagnet, and we discuss its relevance to pertinent experiments.

MA 40.2 Thu 15:15 H 1058

Influence of defects produced by He-ion irradiation on the magnetic properties of the pyrochlore $Ho_2Ti_2O_7$ — •Ena Osmic[1,2], Sumanta Chattopadhyay[1], Thomas Herrmannsdörfer[1], Marc Uhlarz[1], Shavkat Akhmadaliev[3], Uta Lucchessi[3], Stephan Winnerl[3], Geetha Balakrishnan[4], Stefan Facsko[3], Maria Eugenia Toimil-Morales[5], and Joachim Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden, HZDR — [2]Institut für Festkörper- und Materialphysik, TU Dresden — [3]Institut für Ionenstrahlphysik und Materialforschung, HZDR — [4]Department of Physics, University of Warwick, Coventry UK — [5]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

We report on the investigation of changes on the magnetic properties induced by defects produced by He^+-ion irradiation of the spin-ice compound $Ho_2Ti_2O_7$. We irradiated the samples using He^+-ions of 18 MeV energy and different doses. Magnetization M(H) and $M(T)$ measurements revealed that the hallmark of spin-ice compounds, i.e., the appearance of a plateau in M(H), for the irradiated samples looks more defined and can be observed at even higher temperatures compared to the virgin sample. We have also observed systematic changes in the saturation magnetization and the Curie-Weiss temperature T_{CW} compared to the virgin samples. Confocal Raman measurements reveal that the irradiation has induced considerable changes in the oxygen atoms tetrahedrally bonded to the holmium cations. Therefore, we conclude that the changes induced by irradiation are mostly due to the defects produced in the positions of the oxygen atoms.

MA 40.3 Thu 15:30 H 1058

Observation of the spiral spin liquid in a triangular-lattice antiferromagnet $AgCrSe_2$ — •Nikita Andriushin[1], Stanislav Nikitin[2], Øystein Fjellvåg[2,3], Jonathan White[2], Andrey Podlesnyak[4], Dmytro Inosov[1,5], Marcus Schmidt[6], Michael Baenitz[6], and Aleksandr Sukhanov[1] — [1]TU Dresden, Germany — [2]PSI, Switzerland — [3]IFE, Norway — [4]ORNL, USA — [5]ct.qmat, Germany — [6]MPI CPfS, Germany

The spiral spin liquid (SSL) is a highly degenerate state characterized by a continuous contour or surface in reciprocal space spanned by the spiral propagation vector. Although the SSL state has already been discussed for a number of theoretical models, only a very few materials were so far experimentally identified to host such a state. We report an observation of SSL in the quasi-two-dimensional delafossite $AgCrSe_2$, which is an ideal realization of the Heisenberg J_1–J_2–J_3 bond-frustration model on the triangular lattice. To demonstrate this, we combined single-crystal neutron diffraction measurements and microscopic spin-dynamics simulations. Our results show how exotic correlated magnetic states can be induced by a combination of thermal fluctuations and frustration, and establish $AgCrSe_2$ as a model system to study the SSL state.

MA 40.4 Thu 15:45 H 1058

Crystal and magnetic structure changes in $Cu_3SO_4(OH)_4$ under hydrostatic pressure — •Anton Kulbakov[1], Steven Gebel[1], Lukas Keller[2], Denis Cheptiakov[2], Gediminas Simutis[2], Darren Peets[1], and Dmytro Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]PSI, Villigen, Switzerland

A combination of frustration, low-dimensionality, and quantum spin fluctuations in spin-$\frac{1}{2}$ chain systems can introduce extremely high degeneracy and prevent the system from readily selecting a unique ground state. The magnetic order becomes exquisitely sensitive to the balance among the interactions and can be easily tuned among novel magnetically ordered phases. In antlerite, $Cu_3SO_4(OH)_4$, Cu^{2+} ($S = \frac{1}{2}$) quantum spins populate three-leg zigzag ladders in a highly frustrated quasi-one-dimensional structural motif. Previously we presented the magnetic structures at ambient pressure. The application of a hydrostatic pressure on the order of 1 GPa leads to a qualitative change in the magnetic ground state in response to weak structural modifications.

MA 40.5 Thu 16:00 H 1058

Complex magnetic order and inverse magnetic melting in Ce3TiSb5 — •Simon Flury[1,3], Wolfgang Josef Simeth[2], Marc Janoschek[1,3], and Yongkang Luo[4] — [1]University of Zurich, Zurich, Switzerland — [2]Los Alamos National Laboratory, Los Alamos, New Mexiko — [3]Paul Scherrer Institut, Villigen, Switzerland — [4]Huazhong University of Science and Technology, Wuhan, China

We report high-resolution neutron diffraction on the new heavy fermion material Ce3TiSb5. Ce3TiSb5 exhibits an antiferromagnetic order below TN = 5.5 K. Our specific heat and magnetic susceptibility measurements reveal a phase diagram with three distinct magnetic phases. Using neutron diffraction we study the magnetic structure throughout the phase diagram, and uncover a multi-k spin structure in the intermediate field phase. Magnetic multi-k structures are of current interest because they are an important ingredient for topologically non-trivial properties. Finally, our measurements demonstrate that the high-field magnetic phase exhibits inverse melting, where the magnetically ordered state becomes disordered upon cooling. This is a highly unconventional behavior and suggests that the complex magnetic order of Ce3TiSb5 is driven via the competition of several degrees of freedom.

MA 40.6 Thu 16:15 H 1058

Magnon boundstates versus Ising anyons in Kitaev materials — •Tim Bauer[1,2], Lucas R. D. Freitas[2,1], Eric C. Andrade[3], Reinhold Egger[1], and Rodrigo G. Pereira[2] — [1]Institut für Theoretische Physik, Heinrich-Heine-Universität, Düsseldorf, Germany — [2]International Institute of Physics, Universidade Federal do Rio Grande do Norte, Natal, Brazil — [3]Instituto de Física de São Carlos, Universidade de São Paulo, São Carlos, Brazil

We recently predicted that Majorana zero modes (MZMs) near vortices in the quantum spin liquid (QSL) phase of Kitaev materials can be detected in a scanning tunnelling spectroscopy (STS) experiment in terms of a sequence of conductance steps at voltages below the continuum gap [1]. To ensure that the signals of MZMs can be distinguished from trivial excitations, we consider the same experimental setup in the partially polarized phase and the presence of disorder. The excitations of this phase are topological magnons and known to mimic other experimental signatures of the QSL. We report subgap magnon bound states near magnetic impurities modelled by an antiferromagnetic Kondo coupling and studied within spin-wave theory. The bound state energy vanishes only for a critical coupling that flips the impurity or bulk spin. We thus expect these states to behave differently to MZMs in STS when varying the external magnetic field or tunnelling probe position.

[1] Bauer, Tim, et al. Phys. Rev. B 107.5 (2023): 054432

15 min. break

MA 40.7 Thu 16:45 H 1058

Irrational moments and higher-rank gauge theories in diluted classical spin liquids — •Rafael Alvaro Flores Calderon[1], Owen Benton[2], and Roderich Moessner[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, Germany — [2]School of Physical and Chemical Sciences, Queen Mary University of London, London, E1 4NS, United Kingdom

Classical spin liquids (CSLs) have proved fruitful for the emergence of exotic gauge theories. Vacancy clusters in CSLs can introduce gauge charges into the system, and the resulting behavior in turn reveals the nature of the underlying theory. We study these effects for a series of CSLs on the honeycomb lattice. We find that dilution leads to the emergence of effective free spins with tuneable, and generally irrational, size. For a specific higher-rank CSL, described by a symmetric tensor gauge fields, dilution produces *non-decaying* spin textures with a characteristic quadrupolar angular structure, and infinite-ranged interactions between dilution clusters.

MA 40.8 Thu 17:00 H 1058

Magnetic Phase Diagram of Rouaite, $Cu_2(OH)_3NO_3$ — •Darren C. Peets[1], Aswathi Mannathanath Chakkingal[1], Anton A. Kulbakov[1], Maxim Avdeev[2,3], Ramender S. Kumar[4], Issei Niwata[4], Ellen Häussler[5], Roman Gumeniuk[6], J. Ross Stewart[7], Vladimir Pomjakushin[8], Sergey Granovsky[1], Yoshihiko Ihara[4], and Dmytro S. Inosov[1] — [1]Institut für Festkörper- und Materialphysik, TU Dresden, Dresden, Germany — [2]ANSTO, Lucas Heights, NSW, Australia — [3]University of Sydney, Sydney, NSW, Australia — [4]Hokkaido University, Sapporo, Japan — [5]Anorganische Chemie II, TU Dresden, Dresden, Germany — [6]Institut für Experimentelle Physik, TU Bergakademie Freiberg, Freiberg, Germany — [7]ISIS Neutron and Muon Source, Rutherford Appleton Laboratory, Didcot, UK — [8]Paul Scherrer Institute, Villigen, Switzerland

Spinon-magnon mixing was recently reported in botallackite $Cu_2(OH)_3Br$ with a uniaxially compressed triangular lattice of Cu^{2+} quantum spins. Its nitrate analogue rouaite, $Cu_2(OH)_3(NO_3)$, has a highly analogous structure and might be expected to exhibit similar physics. To lay a foundation for research on this material, we report rouaite's magnetic phase diagram and identify both low-field phases. The low-temperature magnetic state comprises alternating ferro- and antiferromagnetic chains as in botallackite, but with some additional canting, while the higher-temperature phase is a helical modulation of this, where the spins rotate from one Cu plane to the next.

MA 40.9 Thu 17:15 H 1058

Kitaev-Heisenberg model on the star lattice – from chiral Majoranas to chiral triplons — •Peru d'Ornellas[1] and Johannes Knolle[1,2,3] — [1]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom — [2]Department of Physics TQM, Technische Universitat Munchen, James-Franck-Straße 1, D-85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

The interplay of frustrated interactions and lattice geometry can lead to a variety of exotic quantum phases. Here we unearth a particularly rich phase diagram of the Kitaev-Heisenberg model on the star lattice, a triangle decorated honeycomb lattice breaking sublattice symmetry. In the antiferromagnetic regime, the interplay of Heisenberg coupling and geometric frustration leads to the formation of valence bond solid (VBS) phases – a singlet VBS and a bond selective triplet VBS stabilized by the Kitaev exchange. We show that the ratio of the Kitaev versus Heisenberg exchange tunes between these VBS phases and chiral quantum spin liquid regimes. Remarkably, the VBS phases host a whole variety of chiral triplon excitations with high Chern numbers in the presence of a weak magnetic field. We discuss our results in light of a recently synthesized star lattice material and other decorated lattice systems.

MA 40.10 Thu 17:30 H 1058

Electric field driven flat bands in S=1/2 sawtooth chain. — Johannes Richter[1,2], •Vadim Ohanyan[3,4], Jörg Schulenburg[5], and Jürgen Schnack[6] — [1]Institut für Physik, Universität Magdeburg, P.O. Box 4120, D-39016 Magdeburg, Germany — [2]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Straße 38, D-01187 Dresden, Germany — [3]Laboratory of Theoretical Physics, Yerevan State University, 1 Alex Manoogian, 0025 Yerevan, Armenia — [4]CANDLE, Synchrotron Radiation Institute, 31 Acharyan Street, 0040 Yerevan, Armenia — [5]Universitätsrechenzentrum, Universität Magde-

burg, D-39016 Magdeburg, Germany — [6]Fakultät für Physik, Universität Bielefeld, Postfach 100131, D-33501 Bielefeld, Germany

We consider one of the paradigmatic models of frustrated spin system, a S=1/2 sawtooth chain with magnetoelectric coupling, realized due to Katsura-Nagaosa-Baladsky (KNB) mechanism. While the magnetic field acts on the spin system via the ordinary Zeeman term, the coupling of an applied electric field with the spins given by the KNB mechanism is effectively realized as a Dzyaloshinskii-Moriya interaction. One can drive the spin system into a flat-band scenario by applying an appropriate electric field, thus overcoming the restriction of fine-tuned exchange couplings. Particularly, if the direction of the electric field coincides with the basal line of the chain, the value of the saturation magnetic field can be reduced. We find a magnetization jump driven by the electric field as well as a jump of the electric polarization driven by the magnetic field, the system exhibits a strong magnetoelectric effect and an enhanced electrocaloric effect.

MA 41: Spintronics (Other Effects)

Time: Thursday 15:00–17:45 Location: H 2013

MA 41.1 Thu 15:00 H 2013

thermal Hall effect from magnon many-body skew scattering — •Dimos Chatzichrysafis and Alexander Mook — Johannes Gutenberg-Universität Mainz, Germany

The thermal Hall effect is a developing tool to investigate charge-neutral excitations, exposing the quantum many-body ground state of correlated materials. A significant aspect regards the nature of excitations (fermions versus bosons) [1]. Although a bosonic thermal Hall effect results from a Berry curvature of quasiparticles, there is mounting evidence that this intrinsic contribution is insufficient to describe experiments [2]. Here, we develop a theory for a magnonic thermal Hall effect driven by many-body skew scattering. To exclude intrinsic effects, we consider a chiral ferromagnet with a single magnon band. The Dzyaloshinskii-Moriya interaction gives rise to many-body interactions that break time-reversal symmetry. Within the framework of the semi-classical Boltzmann equation, we show that a transverse magnon current arises from the skew scattering caused by the interference of three-magnon and four-magnon scattering channels. We estimate that this novel contribution to the thermal Hall effect can be as large as (or even larger than) the intrinsic contribution. Thus, we believe that our work will help better explain related experimental results.

[1] Czajka, P., Gao, T., Hirschberger, M. et al., Nat. Mater. 22, 36-41 (2023)

[2] S. Suetsugu, T. Yokoi, K. Totsuka, T. et al., Phys. Rev. B 105, 024415 (2022)

MA 41.2 Thu 15:15 H 2013

Temperature dependence of disorder effect on the spin current in insulator-metal layered systems — •Mahsa Seyed Heydari, Wolfgang Belzig, and Niklas Rohling — Konstanz University, Konstanz, Germany

We investigate theoretically spin transport through the interface of a non-magnetic metal and an antiferromagnetic insulator driven e.g. by a spin accumulation generated by the spin Hall effect. Our study is motivated by experimental [1] and theoretical [2] work on spin transport through layered systems that include magnetically ordered insulators and non-magnetic metals. Specifically, there is a big interest in the role of thin antiferromagnetic layers. We describe the effect of the interface broadening on the spin current and investigate how disorder-induced broadening of scattering matrix elements with respect to the in-plane momentum influences the spin current. By using Fermi*s Golden rule the spin current can be computed [3]. Our results allow insights into the temperature dependence of the interface-disorder-induced influence on the spin current. In general, we find that increasing disorder leads to a decrease in spin current. Additionally, for a magnetically compensated interface, we find a thermal-gradient contribution to the spin current (spin Seebeck effect) only as a higher-order effect.

[1] Pati, Materials Letters 299, 130088 (2021)

[2] Gulbrandsen, Brataas, Phys. Rev. B 97, 054409 (2018)

[3] Fj*rbu et al., Phys. Rev. B 95, 144408 (2017)

MA 41.3 Thu 15:30 H 2013

Non-hermiticity in spintronics: oscillation death and stochastic control of stability in coupled spintronic oscillators — •Steffen Wittrock[1,2], Salvatore Perna[3], Romain Lebrun[2], Katia Ho[2], Roberta Dutra[4], Ricardo Ferreira[5], Paolo Bortolotti[2], Claudio Serpico[3], and Vincent Cros[2] — [1]Helmholtz-Zentrum Berlin, Berlin, Germany — [2]Unité Mixte de Physique CNRS, Thales, Palaiseau, France — [3]University of Naples Federico II, Naples, Italy — [4]Centro Brasileiro de Pesquisas Fésicas, Rio de Janeiro, Brazil — [5]International Iberian Nanotechnology Laboratory, Braga, Portugal

The potential of non-hermitian physics in spintronics is just about to be discovered and anticipated to uncover a manifold of intriguing phenomena and potential applications. In a system of coupled spintronic oscillators, we have just recently demonstrated the phenomenon of amplitude death to occur in the vicinity of an exceptional point, connecting nonlinear physics with the principles of non-hermiticity. Here, we present the control of the coupled oscillator stability and occuring stochastics in the vicinity of an exceptional point.

MA 41.4 Thu 15:45 H 2013

Thin film heterostructures based on Co/Ni synthetic antiferromagnets on polymer tapes: towards a sustainable flexible spintronics — •Mariam Hassan[1,2], Sara Laureti[2], Christian Rinaldi[3], Federico Fagiani[3], Gianni Barucca[4], Francesca Casoli[5], Alessio Mezzi[6], Eleonora Bolli[6], Saulius Kaciulis[6], Aladin Ulrich[1], Gaspare Varvaro[2], and Manfred Albrecht[1] — [1]University of Augsburg, Germany — [2]CNR-ISM, Italy — [3]Politecnico di Milano, Italy — [4]Politecnica delle Marche, Italy — [5]CNR-IMEM, Italy — [6]CNR-ISMN, Italy

Compared to platinum-group metal systems (PGMs), the PGMs-free Co/Ni-system offers several advantages for spin-based devices such as low damping and high spin polarization, and they contribute to a more sustainable future by relieving the demand for strategic raw materials. In this work, flexible synthetic-antiferromagnets with perpendicular-magnetic-anisotropy (PMA-SAFs) and GMR-spin-valves (SVs) containing a SAF-reference electrode and a Co/Ni-free layer were deposited on flexible polyethylene naphthalate tapes with different combinations of buffer and capping layers (Pt, Pd, Cu/Ta). High-quality SAFs with a fully compensated antiferromagnetic region and SVs with a sizeable GMR ratio were obtained. The best performances are achieved with PGMs used as buffer layer and Cu as capping layer[1]. The results indicate that complex Co/Ni-based heterostructures with reduced content of PGMs deposited on flexible tapes allow for the development of novel shapeable and sustainable spintronic devices. [1]ACS Appl. Mater. Interfaces. 14 (2022) 51496-51509.

MA 41.5 Thu 16:00 H 2013

Oxygen-Vacancies-Driven Resistive Switching in Epitaxial Fe_3O_4 Thin Films — •Yifan Xu[1,2], Connie Bednarski-Meinke[2], Steffen Tober[2], Asmaa Qdemat[2], Felix Gunkel[3], Regina Dittmann[3], Oleg Petracic[2,1], and Mai Hussein Hamed[2,4] — [1]Heinrich Heine University Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf, Germany — [2]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Peter Grünberg Institute and JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [4]Faculty of Science, Helwan University, Cairo, Egypt

Resistive switching implies that the device can be switched between a High Resistance State (HRS) and Low Resistance State (LRS) upon application of an electric field. Fe_3O_4 emerges as a candidate for resistive switching due to the sensitivity of its magnetic and electronic properties on the presence of oxygen vacancies. Here we present the preparation and characterization of epitaxial Fe_3O_4 thin films grown on TiO_2 - terminated Nb:$SrTiO_3$ via pulsed laser deposition (PLD). We observe resistive switching using I-V measurements and magnetometry. We propose a mechanism in which redox reactions and the presence of oxygen vacancies are responsible for the resistive switching. This effect shows potential for next-generation magnetoionic device applications.

MA 41.6 Thu 16:15 H 2013

Role of vibronic coupling in the chirality-induced spin selectivity effect in electron transport through chiral molecules — •Rudolf Smorka, Yaling Ke, and Michael Thoss — Institute of Physics, University of Freiburg, Germany

The chirality-induced spin selectivity effect, which is the spin-dependent transmission of electrons through chiral materials, has attracted considerable interest for its potential applications in spintronics, electrochemistry, and optoelectronics, as well as shedding light on spin-selective chemical reactions and biological processes [1]. This effect, observed in various materials like double-stranded DNA, emerges from the interplay between geometrical helicity and spin-orbit interactions and is a nonequilibrium phenomenon.

Existing theoretical models, while reproducing experimental findings, often rely on unrealistic spin-orbit interaction parameters, possibly due to neglecting electron correlations. A recent vibrationally assisted spin-orbit coupling model shows promise for achieving high spin selectivities [2]. Our investigation of this model employs two methodologies: a mixed quantum-classical approach combining Ehrenfest dynamics with hierarchical equations of motion (HEOM), and a recently introduced numerically exact HEOM in matrix product state formulation [3], offering a comparative study of the role of vibrations on spin selectivity in this model.

[1] Evers, F. *et al.*, *Adv. Mater.* **34**, 2106629 (2022)
[2] Fransson, J., *Phys. Rev. B* **102**, 235416 (2020)
[3] Ke, Y., Borrelli, R., Thoss, M., *J. Chem. Phys.* **156.19** (2022)

15 min. break

MA 41.7 Thu 16:45 H 2013

Spin-splitting in collinear antiferromagnetic MnTe : Inception and manifestations — •Jan Minár[1], Sunil Wilfred Dsouza[1], Juraj Krempaský[2], Libor Šmejkal[3,4], Jan Hugho Dil[5,2], and Tomáš Jungwirth[4,6] — [1]New Technologies Research Centre, University of West Bohemia, Univerzitní 8, CZ-306 14 Pilsen, Czech Republic. — [2]Photon Science Division, Paul Scherrer Institut, CH-5232 Villigen, Switzerland. — [3]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany. — [4]Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6 Czech Republic. — [5]Institut de Physique, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland. — [6]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom

We have explored Kramers spin non-degenerate states in MnTe by investigating the spin-polarized electronic structure of MnTe by means of one-step model Angle Resolved photoemission (ARPES) calculations within the fully relativistic multiple scattering Korringa-Kohn-Rostoker Green function approach. ARPES spectral weight related to non-symmorphic symmetry and signatures corresponding to the surface resonance contributions from Te and Mn states at respective binding energies were identified. Excellent agreement between theory and experiments reveals that the spin splitting stems from the local crystal anisotropy without requiring strong electronic correlations[1].

[1] J. Krempaský et al.,(2023),arXiv:2308.10681 (Accepted in Nature)

MA 41.8 Thu 17:00 H 2013

Interfacial Engineering of the magnetism and spin transport in two-dimensional materials — •Haichang Lu[1,2], John Robertson[2], Zhimei Sun[3], and Weisheng Zhao[1] — [1]Fert Beijing Institute, MIIT Key Laboratory of Spintronics, School of Integrated Circuit Science and Engineering, Beihang University, Beijing, 100191, China — [2]Engineering Department, Cambridge University, Cambridge CB2 1PZ, UK — [3]School of Materials Science and Engineering, Beihang University, Beijing 100191, China

Two-dimensional (2D) materials are promising candidates for the next generation of spintronic devices as they provide flat interfaces that embed many interesting physical effects. As the device size shrinks, properties such as magnetism and spin transport are not only determined by the materials but also by the interfaces. Here, we study the interfacial effects. For example, Fe4GeTe2 is a quasi-2D ferromagnet with an intrinsic Curie temperature (TC) approaching 300K. We show that by contacting with sapphire 001 surface, the Curie temperature can rise to 530K. We also study CrTe2, another ferromagnetic metal with TC approaching room temperature. We find spin frustration happens in monolayer CrTe2, but the substrate recovered the ferromagnetism. Apart from TC, we also show that the type of interface, such as physisorbed and chemisorbed interface, pose a significant impact on the spin transport. We investigate the tunnel magnetoresistance (TMR) effect of the hexagonal boron nitride (h-BN)/Co magnetic tunnel junction. TMR with physisorbed interfaces is 1000 times higher than that of chemisorbed interfaces.

MA 41.9 Thu 17:15 H 2013

Search for ferromagnetism in Mn-doped lead halide perovskites — •Maryam Sajedi[1], Chen Luo[1], Konrad Siemensmeyer[1], Maxim Krivenkov[1], Kai Chen[1,2], James M. Taylor[1,3], Marion A. Flatken[1], Florin Radu[1], and Oliver Rader[1] — [1]Helmholz-Zentrum Berlin für Materialien und Energie — [2]National Synchrotron Radiation Laboratory, university of Science and Technology of China, — [3]Fakultät für Physik, Technische Universität München,

Lead halide perovskites are new key materials in various application areas such as high efficiency photovoltaics, lighting, and photodetectors. Doping with Mn, which is known to enhance the stability, has recently been reported to lead to ferromagnetism below 25 K in methylammonium lead iodide (MAPbI3) mediated by superexchange. Two most recent reports confirm ferromagnetism up to room temperature but mediated by double exchange between Mn2+ and Mn3+ ions. Here we investigate a wide concentration range of MAMnxPb1*xI3 and Mn-doped triple-cation thin films by soft X-ray absorption, X-ray magnetic circular dichroism, and quantum interference device magnetometry. The X-ray absorption lineshape shows clearly an almost pure Mn2+ configuration, confirmed by a sum-rule analysis of the dichroism spectra. A remanent magnetization is not observed down to 2 K. Curie-Weiss fits to the magnetization yield negative Curie temperatures. All data show consistently that significant double exchange and ferromagnetism do not occur. Our results show that Mn is not suitable for creating ferromagnetism in lead halide perovskites.

MA 41.10 Thu 17:30 H 2013

Strong tuning of Rashba spin-orbit coupling and crossover from weak localization to weak antilocalization in ionic-gated tellurium — •Dorsa Fartab[1], José Guimarães[1,2], Marcus Schmidt[1], and Haijing Zhang[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]School of Physics and Astronomy, University of St Andrews, St Andrews KY16 9SS, United Kingdom

Electrostatic control of the charger carrier density inside the solids is an important factor to realize different phase transitions in two-dimensional materials such as insulator-metal transition and superconductivity. Moreover, the gate control of electron spin in materials with high spin-orbit coupling (SOC) is a key factor in the field of spintronics. Here, I will first provide a brief overview of electric double layer transistors (EDLTs) and highlight the advantages of utilizing ionic liquids as the dielectric medium over conventional solid dielectrics; then, I will present our experimental results of ionic liquid gated p-type tellurium (Te). Our results show the possibility of gate tuning insulator-metal transition and the crossover from weak localization (WL) to weak antilocalization (WAL) into the sample, implying an increased Rashba-like SOC in the material created by a strong electric field restricted to the solid/electrolyte interface in EDLTs. More interestingly, we have demonstrated the ability to control the electron spin and amplify the Rashba parameter by a factor of 4 through ionic gating Te, which could have potential applications in the field of spintronics.

MA 42: Spin Transport and Orbitronics, Spin-Hall Effects II (joint session MA/TT)

Time: Thursday 15:00–16:00 Location: EB 107

MA 42.1 Thu 15:00 EB 107

Controlling the Interlayer Dzyaloshinskii-Moriya Interaction by Electrical Currents — •Fabian Kammerbauer[1], Won-Young Choi[1], Freimuth Frank[1,2], Robert Frömter[1], Yuriy Mokrousov[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The recently discovered interlayer Dzyaloshinskii-Moriya interaction (IL-DMI) in multilayers exhibiting perpendicular magnetic anisotropy induces a canting of spins in the in-plane direction, potentially stabilizing intriguing spin textures like Hopfions [1]. Nucleation control becomes pivotal, prompting our exploration into the impact of electric currents on IL-DMI strength–a phenomenon previously established for DMI [2]. To quantify IL-DMI, we use out-of-plane hysteresis loops, applying a static in-plane magnetic field at varied azimuthal angles. A notable observation emerges: a shift in azimuthal dependence with increasing current. This shift is attributed to an additional in-plane symmetry breaking introduced by the electrical current. Detailed fitting substantiates the presence of an additive current-induced term [3]. This unveils a practical avenue for manipulating 3D spin textures on-the-fly via a readily accessible method.

[1] Han et al., Nat. Mater. 18, 703-708 (2019)
[2] Karnad et al., Phys. Rev. Lett. 121, 147203 (2018)
[3] Kammerbauer et al, Nano Lett. 2023, 23, 15, 7070-7075 (2023)

MA 42.2 Thu 15:15 EB 107

Local violation of the reciprocity between the direct and inverse orbital Hall effects — •Dongwook Go[1,2], Tom S. Seifert[3,4], Tobias Kampfrath[3,4], Stefan Blügel[1], Hyun-Woo Lee[5], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg Universität Mainz, Mainz, Germany — [3]Department of Physics, Freie Universität Berlin, Berlin, Germany — [4]Department of Physical Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [5]Department of Physics, Pohang University of Science and Technology, Pohang, Korea

We theoretically investigate the reciprocity between the direct and inverse orbital Hall effects [1]. We show that the reciprocal relation between charge and orbital transport can be rigorously established by adopting the definition of the *proper* current that takes nonconservation effects into account [2]. Importantly, we find that the local reciprocity of charge and orbital currents is violated in thin films, as we demonstrate for the case of W(110) from first principles. Our results explain a seemingly inconsistent behavior of direct and inverse orbital Hall effect observed in recent experiments, where the two phenomena are found to be dominant in bulk and at surfaces, respectively [3,4]. References: [1] Go *et al.* In Preparation; [2] Shi *et al.* Phys. Rev. Lett. **96**, 076604 (2007); [3] Hayashi *et al.* Commun. Phys. **6**, 32 (2023); [4] Seifert *et al.* Nat. Nanotechnol. **18**, 1132 (2023).

MA 42.3 Thu 15:30 EB 107

Spin-orbitronics in two dimensional systems: Orbital magnetization, orbital Hall effect and orbital Edelstein effect — •Börge Göbel[1], Oliver Busch[1], Annika Johansson[2], Manuel Bibes[3], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle — [3]Unité Mixte de Physique, CNRS, Thales, Paris

The orbital contribution to the magnetization is often quenched by the crystal field which is why it is typically significantly smaller than the spin contribution, in equilibrium. In this talk, I will present the generation of a large orbital magnetization and orbital currents.

In non-collinear spin textures, crystal symmetries are broken and the quenching is lifted. In topologically non-trivial skyrmion crystals, for example, the emergent field forces electrons on orbital trajectories which leads to the generation of a considerable orbital magnetization [1]. Likewise, an orbital Hall effect with orbital edge states arises in non-magnetic Kagome nanoribbons [2]. In two-dimensional electron gases (2deg), e.g. at the interface of STO/AlO [3,4] or KTO/AlO [5], the inversion symmetry is broken so that an (inverse) Edelstein effect arises. The application of a charge current leads to the generation of spin and orbital magnetization densities and vice versa.

[1] BG et al. PRB 99, 060406 (2019)
[2] Busch, Mertig, BG, PRResearch 5, 043052 (2023)
[3] Vaz, BG et al. Nature Materials 18, 1187 (2019)
[4] Johansson, BG et al. PRResearch 3, 013275 (2021)
[5] Varotto, BG et al. Nature Communications 13, 6165 (2022)

MA 42.4 Thu 15:45 EB 107

Spin Fluctuation Enhancement of Spin Hall Effect in Low-resistive Antiferromagnet — •Chi Fang and Stuart S.P. Parkin — Max Planck Institute of Microstructure Physics, Halle (Saale) 06120, Germany

The spin Hall effect (SHE) generates a pure spin current by a charge current, which is promisingly adopted to electrically manipulate magnetization. To reduce power consumption of such control, a giant spin Hall angle (SHA) in the SHE is expected in low-resistive systems for practical applications. Low resistive antiferromagnet Chromium(Cr) is reported with remarkble SHA. Here, critical spin fluctuation near the antiferromagnetic (AFM) phase-transition in Cr is proved as an effective mechanism to further create an additional part of SHE. The SHA is significantly enhanced when temperature approaches the Néel temperature of Cr and has a peak value of -0.36 near the Néel temperature. This value is higher than the room-temperature value by 153% and leads to a low normalized power consumption among known spin-orbit torque (SOT) materials. This study demonstrates the critical spin fluctuation as a prospective way of increasing SHA and enriches the AFM material candidates for spin-orbitronic devices.

MA 43: Magnetic Semiconductors, Magnetization Dynamics and Damping

Time: Thursday 15:00–17:15 Location: EB 202

MA 43.1 Thu 15:00 EB 202

Low-energy properties of electrons and holes in CuFeS2 — •Bjørnulf Brekke[1], Roman Malyshev[2], Ingeborg-Helene Svenum[3,4], Sverre M. Selbach[5], Thomas Tybell[2], Christoph Brüne[1], and Arne Brataas[1] — [1]Center for Quantum Spintronics, Department of Physics, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [2]Department of Electronic Systems, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [3]Department of Chemical Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway — [4]SINTEF Industry, Trondheim, Norway — [5]Department of Materials Science and Engineering, NTNU Norwegian University of Science and Technology, Trondheim, Norway

The antiferromagnetic semiconductor CuFeS2 belongs to a magnetic symmetry class that is of interest for spintronics applications. In addition, its crystal lattice is compatible with Si, making it possible to integrate it with nonmagnetic semiconducting structures. Therefore, we investigate this material by finding the effective k*p Hamiltonian for the electron and hole bands. We base this description on ab initio calculations and classify the electronic bands by their symmetry. As a result, we find that CuFeS2 exhibits spin-polarized bands. We also find that the crystal symmetry allows for the anomalous Hall effect. Finally, we suggest using cyclotron resonance to verify our proposed effective mass tensors at the conduction band minimum and valence band maximum.

MA 43.2 Thu 15:15 EB 202

Gate-Controlled Magnetic Properties of the 2D Semiconductor $CrPS_4$ — •Nicolas Ubrig[1], Fan Wu[1], Ignacio Gutiérrez lezama[1], Marco Gibertini[2], and Alberto Morpurgo[1] — [1]Department of Quantum Matter Physics, University of Geneva — [2]Dipartimento di Scienze Fisiche, Informatiche e Matematiche, University of Modena and Reggio Emilia

Using field-effect transistors (FETs) to explore atomically thin magnetic semiconductors with transport measurements is difficult, because the very narrow bands of most 2D magnetic semiconductors cause carrier localization, preventing transistor operation. Here, we show that exfoliated layers of $CrPS_4$ –a 2D layered antiferromagnetic semiconductor whose bandwidth approaches 1 eV– allow the realization of FETs that operate properly down to cryogenic temperature. Using these devices, we perform conductance measurements as a function of temperature and magnetic field, to determine the full magnetic phase diagram, which includes a spin-flop and a spin-flip phase. We find that the magnetoconductance depends strongly on gate voltage, reaching values as high as 5000 % near the threshold for electron conduction. The gate voltage also allows the magnetic states to be tuned, despite the relatively large thickness of the $CrPS_4$ multilayers employed in our study. Our results show the need to employ 2D magnetic semiconductors with sufficiently large bandwidth to realize properly functioning transistors, and identify a candidate material to realize a fully gate-tunable half-metallic conductor.

MA 43.3 Thu 15:30 EB 202

Electronic structure of bulk and ultrathin CrSBr: an ARPES study — •Marco Bianchi[1], Swagata Acharya[2,3], Florian Dirnberger[4], Julian Klein[5], Kimberly Hsieh[1], Esben J. Porat[1], Dimitar Pashov[6], Kseniia Mosina[7], Zdenek Sofer[7], Alexander Rudenko[3], Mikhail I. Katsnelson[3], Mark van Schilfgaarde[6,2], Yong P. Chen[1,8], Malte Rösner[3], and Philip Hofmann[1] — [1]Dep. of Phys. & Astro., ISA, iNANO, Aarhus Univ., DK — [2]National Renewable Energy Labb., Golden, CO, USA — [3]Inst. for Molecules & Matt., Radboud Univ., Nijmegen, NL — [4]Inst. App. Phys. & ct.qmat, Tech. Univ. Dresden, DE — [5]Dep. Matt. Sci. & Eng., MIT, Cambridge, MA, USA — [6]Kings College, Theory & Simulation of Cond. Mat., London, UK — [7]Dep. Inorganic Chem., Univ. of Chem. & Tech., Prague, CZ — [8]Dep. of Phys. & Astro., Purdue Quantum Sci. & Eng. Inst., Purdue Univ., West Lafayette, IN, USA

We explore the electronic structure of paramagnetic bulk and ultrathin flakes of CrSBr, exfoliated in situ on Au(111) and Ag(111) using angle-resolved photoemission spectroscopy. The observed band structure in the two cases is drastically different: While the bulk charges up at temperatures lower than 200 K and requires ab-intio GW calculation to be interpreted, the ultrathin flakes can be measured down to 35 K, are n-doped and well described by DFT calculations if local Coulomb interactions are taken into account.

MA 43.4 Thu 15:45 EB 202

Light-induced alignment of Mn spins in hybrid metal halide perovskite matrix — •Stanislav Bodnar, Jonathan Zerhoch, Shangpu Liu, Andrii Shcherbakov, and Felix Deschler — Physikalisch-Chemisches Institut, Universität Heidelberg, Im Neuenheimer Feld 229, 69120 Heidelberg, Germany

Hybrid organic-inorganic metal-halide perovskites (HOIPs) are prospective semiconductor materials for a new generation of solar cells and light emission diodes (LEDs) as well as a new class of material for data storage applications. In our work, we investigated highly Mn-doped MAPbBr3 (MA=methylamine) with a nominal doping level of Mn2+ at the level of 50%. The incorporation of Mn atoms has led to the presence of a new paramagnetic state of the Mn-doped material without forming a ferromagnetic or antiferromagnetic spin order. Our studies have revealed that the transient Faraday signal in the Mn-doped sample is 3 times higher than in the case of undoped MAPbBr3. We attribute this additional Faraday signal in the Mn-doped sample to the magnetic moments associated with Mn spins which are aligned by an effective magnetic field caused by light-induced spin-polarized charge carriers. Additionally, we discovered that the presence of Mn atoms in the MAPbBr3 has led not only to the enhanced amplitude of the transient Faraday signal but also to the extended spin lifetime. For the moderate fluence regime of 100 uJ/cm2 spin lifetime of the Mn-doped sample has been extended by 3 times (15ps) compared to the undoped sample. We attribute this extended spin lifetime to the presence of the additional aligned Mn spins.

15 min. break

MA 43.5 Thu 16:15 EB 202

Transmission Line Resonators and Lumped Element Resonators for Strong Coupling — •Anoop Kamalasanan — Martin Luther University Halle-Wittenberg

Superconducting (SC) resonators and their seamless integration have proven critical in recent progress of on-chip quantum systems. Specifically, they are commonly implemented as a primary component in hybrid quantum systems due to their high-Q resonance properties and their ability to couple various quantized excitations (e.g. magnons, photons, phonons). Devices based on SC resonators have demonstrated numerous instances of strong coupling. Coupled microwave photon-magnon systems have received great attention as an alternative approach to realize strong light-matter interactions using magnetic dipole coupling.

In this work, we present the fabrication and characterization of superconducting resonators, namely $\lambda/2$ resonator and lumped-element resonator, alongside simulations of their microwave transmission properties. After optimizing the design of these waveguides with finite element method simulations, NbN-based superconducting resonators are fabricated for magnon-based investigations of strong coupling.

MA 43.6 Thu 16:30 EB 202

Magnetoelastic coupling to transverse and longitudinal phonons revealed by broadband ferromagnetic resonance — •Luise Siegl[1], Julie Střihavková[2], Richard Schlitz[1], Hans Huebl[3,4,5], and Sebastian T. B. Goennenwein[1] — [1]Department of Physics, University of Konstanz — [2]Faculty of Mathematics and Physics, Charles University, Prague — [3]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [4]TUM School of Natural Sciences, Technische Universität München, Garching — [5]Munich Center for Quantum Science and Technology (MCQST), München

In ferromagnetic thin films, magnetization dynamics driven, e.g. by ferromagnetic resonance, can coherently couple to phonons. These phonons are subsequently "pumped" into the underlying substrate, such that the process is also referred as phonon pumping. When opposite sides of the sample stack are parallel and polished, the sample forms a bulk acoustic resonator, so that standing sound waves are formed. The magnetoelastic coupling to longitudinal and transverse phonons should exhibit a particular dependence on the orientation of the magnetic field [1]. In this work, we analyze the magnetoelastic coupling depending on the magnetic field orientation in thin yttrium iron garnet films on single crystal gadolinium gallium garnet substrates. From our broadband ferromagnetic resonance measurements, we extract the coupling strength as a function of field orientation and critically compare them to the theoretical predictions.

[1] T. Sato, et al., Phys. Rev. B **104**(1), 014403 (2021).

MA 43.7 Thu 16:45 EB 202

Lattice damping: a first attempt from tight-binding — •Zhiwei Lu[1], Ivan Miranda[2], Manuel Pereiro[2], Anders Bergman[2], Erik Sjöqvist[2], Olle Eriksson[2], Anna Delin[1], and Danny Thonig[3] — [1]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Sweden — [3]School of Science and Technology, Örebro University, Sweden

In recently emerging coupled spin-lattice dynamics, it has been revealed that the energy dissipation in lattice dynamics (lattice damping) has a strong impact on the demagnetization rate [1]. However, the lattice damping remains the only parameter yet to be theoretically quantified. Here we present a new method to calculate the nonlocal lattice damping tensor using a Tight-binding approach implemented in Cahmd [2], with application on iron and cobalt. The lattice damping is calculated with a range of electron lifetimes and electron temperature. Given that the dissipation force's sum rule must adhere to Newton*s third law, the effective lattice damping (as observed in coherent phonon code) is zero. Furthermore, our results reveal that the lattice damping shows significant correlation to the density of states at Fermi level, which is similar to spin damping. Our work not only proposes a novel methodological framework to calculating lattice damping but also paves the way for deeper insights into the lattice dynamics of materials.

[1]Phys. Rev. B 106, 174407(2022) [2]available at https://cahmd.gitlab.io/cahmdweb/

MA 43.8 Thu 17:00 EB 202

Anisotropic Gilbert damping in reduced dimensions from theoretical calculations — Balázs Nagyfalusi[1,2], László Szunyogh[2], and •Krisztián Palotás[1,2] — [1]Wigner Research Center for Physics, Budapest, Hungary — [2]Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

The energy-dissipative damping process plays an important role in magnetization dynamics. The in-depth understanding of the magnetization damping is crucial for the development of spintronic applications in the future. Based on a recently implemented ab initio calculation method of the diagonal elements of the atomic-site-dependent Gilbert damping tensor within the real-space Screened Korringa-Kohn-Rostoker (SKKR) framework, anisotropy effects of the Gilbert damping are studied. For (001)-oriented surfaces of ferromagnetic Fe and Co it is pointed out that in the vicinity of the surface the corresponding transverse Gilbert damping tensor components are substantially varied depending on the magnetization direction. This effect is even more enhanced considering monolayer-thick 2D films of Fe and Co studied on noble metal surfaces. Finally, taking Fe and Co single adatoms and magnetic dimers, the occurrence of anisotropic damping is also demonstrated. The effect of the identified anisotropic dampings should be included into future spin dynamics simulations aiming at an improved accuracy.

MA 44: Non-Skyrmionic Magnetic Textures

Time: Thursday 15:00–17:45 Location: EB 301

Invited Talk MA 44.1 Thu 15:00 EB 301

Synthetic antiferromagnets with ferromagnetic domains separated by antiferromagnetic domain walls — •Ruslan Salikov[1], Fabian Samad[1,2], Sebastian Schneider[3], Darius Pohl[3], Bernd Rellinghaus[3], Jürgen Lindner[1], Nikolai Kiselev[4], and Olav Hellwig[1,2] — [1]HZDR, Dresden, Germany — [2]TU Chemnitz, Chemnitz, Germany — [3]TU Dresden, Dresden, Germany — [4]Forschungszentrum Jülich, Jülich, Germany

Magnetic nanostructures, such as magnetic domains or magnetic solitons, hold significant potential for advancing data processing, storage, and neuromorphic type of applications. Through the utilization of $[[Co/Pt]_{X-1}/Co/Ru]_{N-1}[Co/Pt]_X$ multilayer metamaterials, we stabilize mixed ferromagnetic/antiferromagnetic (FM/AF) textures. These textures exhibit FM perpendicular stripe and bubble domains, separated by AF Bloch-type domain walls. The acquired bubble domains, characterized by alternating chirality, unveil a promising avenue for three-dimensional memory and logic, combined with the skyrmionic race track memory concept.

MA 44.2 Thu 15:30 EB 301

Tracking the field-induced motion of three-dimensional nanoscale topological magnetisation textures — •Jeffrey Neethi Neethirajan[1], Nicholas William Phillips[2], Marisel Di Pietro Martinez[1], Luke Turnbull[1], Valerio Scagnoli[2,3], Simone Finizio[2], Lars Heller[2], Sandra Ruiz Gomez[1], Klaus Wakonig[2], Mirko Holler[2], Manuel Guizar-Sicairos[2,4], and Claire Donnelly[1,5] — [1]MPI-CPfS, Dresden, Germany — [2]PSI, Villigen, Switzerland — [3]ETH, Zurich, Switzerland — [4]EPFL, Lausanne, Switzerland — [5]WPI-SKCM2, Hiroshima, Japan

Imaging of the nanoscale magnetic configuration of extended systems offers the possibility to study topological magnetic textures in three-dimensional (3D) real space. Indeed, since the development of X-ray magnetic vector tomography and laminography, the static magnetisation configuration of Bloch points, vortex rings and torons has been elucidated. However, it has not yet been possible to directly observe the response of such 3D textures to stimuli such as applied magnetic fields. Here, we image 3D magnetic configuration of a bulk GdCo2 ferrimagnet, which consists of a complex network of topological textures and singularities. By performing field-dependent X-ray magnetic laminography, we track the field-driven response of the 3D magnetic configuration, and observe the propagation of textures in the magnetisation in 3D space. In this way, we are able to gain insights into the creation, propagation and annihilation of topological magnetization textures from quasi-static measurements, important both fundamentally as well as for prospective technologies.

MA 44.3 Thu 15:45 EB 301

Non-coplanar helimagnetism in the layered van-der-Waals metal DyTe$_3$ — Shun Akatsuka[1], •Sebastian Esser[1], Jonathan White[2], Rinsuke Yamada[1], Seno Aji[3], Shang Gao[4], Yoshichika Onuki[5], Taka-hisa Arima[1,5], Taro Nakajima[3,5], and Max Hirschberger[1,5] — [1]University of Tokyo, Japan — [2]PSI, Switzerland — [3]ISSP, University of Tokyo, Japan — [4]University of Science and Technology of China, China — [5]RIKEN CEMS, Japan

Layered van-der-Waals (vdW) materials are typified by highly anisotropic chemical bonds, enabling exfoliation to realize ultrathin sheets or interfaces. When combined with magnetism, such materials are promising candidates for novel cross-correlation phenomena between electric polarization and the magnetic texture itself. However, the vast majority of these vdW magnets are collinear ferro-, ferri-, or antiferromagnets, with a particular scarcity of lattice-incommensurate helimagnets of well-defined left- or right-handedness. Here we report on the magnetic order of DyTe$_3$, where insulating double-slabs of Dy-square nets are separated by highly metallic Te-layers.

This cleavable metallic helimagnet hosts a complex magnetic phase diagram, indicative of competing interactions. At high temperatures, above the transition to three-dimensional long-range order, we observe evidence for short-range correlations in individual two-dimensional structural block layers. Our work paves the way for twistronics research, where helimagnetic layers can be combined to form complex spin textures on-demand, using the vast family of rare earth chalcogenides, and beyond.

MA 44.4 Thu 16:00 EB 301

Local control over chiral textures with curvilinear helimagnets — •Luke Turnbull[1], Max Birch[2], Marisel Di Pietro Martinez[1], Rikako Yamamoto[1,3], Jeffrey Neethirajan[1], Marina Raboni Ferreira[1,4], Simone Finizio[5], Sebastian Wintz[6], Rachid Belkhou[7], Claas Abert[8], Dieter Suess[8], and Claire

Donnelly[1] — [1]MPI-CPfS, Dresden, Germany — [2]RIKEN CEMS, Saitama, Japan — [3]WPI-SKCM2, Hiroshima, Japan — [4]LNLS, São Paulo, Brazil — [5]PSI, Villigen, Switzerland — [6]HZB, Berlin, Germany — [7]SOLEIL, Saint Aubin, France — [8]University of Vienna, Vienna, Austria

Precise control over the magnetic energy landscape is key for the stabilisation and control of topological magnetisation textures. Until now this has been commonly achieved with the bulk Dzyaloshinskii-Moriya interaction (DMI), a chiral interaction that arises due to broken crystalline inversion symmetry. But recently, there have also been proposals to make use of geometric symmetry breaking with curvature. Here we combine intrinsic and extrinsic interactions in patterned toroidal helimagnets, resulting in a locally varying DMI. Specifically, by patterning nanoscopic tori of single crystal helimagnets and imaging their magnetisation configuration using x-ray ptychographic imaging, we observe the presence of a radial curvature-induced helical texture, that we confirm with finite element micromagnetic simulations. Our work highlights the impact of curvature on chiral helimagnetism, offering opportunities to tailor chiral magnetic textures within curvilinear geometries.

MA 44.5 Thu 16:15 EB 301

Screw dislocations and fractional hopfion rings in chiral magnets — •Maria Azhar — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

In chiral magnets, topological defects such as Skyrmions and Hopfions are typically considered in a ferromagnetic background. Recently we predicted that helical phases offer a plethora of novel topological spin textures including screw dislocations where the helical order locally arranges as a spiral staircase [1]. These new topological spin structures, which appear in many facets and look very different locally, have the remarkable property that their far field is universally determined by a topological index ν characterizing the dislocation. Intriguingly, we identify screw dislocations with a smooth magnetic core and a simple screw structure ($\nu = +1$), that can be continuously deformed either to vortices of the XY-order parameter or to vortex strings encircled by fractional Hopfion rings. The latter prediction has recently been experimentally confirmed by means of transmission electron microscopy [2]. Another astonishing spin structure that we predicted arises from a singular core comprising a chain of Bloch points with alternating topological charge. Our findings enrich the portfolio of topological magnetic structures ubiquitously being present in bulk and thin-film helimagnets and will play a crucial role on the way to 3D nanomagnet and spintronics applications.

[1] M. Azhar, V. Kravchuk, and M. Garst, PRL 128, 157204 (2022)
[2] F. Zheng, et al. Nature 623, 718 (2023).

15 min. break

MA 44.6 Thu 16:45 EB 301

Spacetime Magnetic Hopfions from Internal Excitations and Braiding of Skyrmions — •Ross Knapman[1,2], Timon Tausendpfund[2], Sebastián A. Díaz[1,3], and Karin Everschor-Sitte[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Duisburg 47057, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [3]Department of Physics, University of Konstanz, 78457 Konstanz, Germany

Magnetic hopfions are three dimensional topological magnetic textures for which the topology is typically defined in terms of space, and time plays only a secondary role in terms of the structures' dynamics. We construct the "spacetime magnetic hopfion", in which the temporal dimension plays an active role in the definition of the structure's topology [1]. We use two approaches: the rotation of a skyrmion's helicity in a frustrated magnet, and the braiding of two skyrmions around one another. The emphasis is placed on the first case, where we use a Ginzburg-Landau description of the system [2] to model the skyrmion's internal modes using micromagnetic and collective coordinate modelling. In tuning the time dependence of the externally applied electric field, we show that it is possible to induce dynamics which realise spacetime magnetic hopfions. We envisage such structures to exist in other areas of physics, outside of magnetic systems.

[1] Knapman, R., Tausendpfund, T., Díaz, S. A., Everschor-Sitte, K., arXiv:2305.07589 (2023).
[2] Lin, S. Z., Hayami, S., Phys. Rev. B **93**, 064430 (2016).

MA 44.7 Thu 17:00 EB 301

From Ferromagnetic Magnetostatics to Antiferromagnetic Topology: Antiferromagnetic Vortex States in NiO-Fe Nanostructures — Michał Ślezak[1], •Tobias Wagner[2], V.K. Bharadwaj[2], Anna Kozioł-Rachwał[1], Tomasz Ślezak[1], and Olena Gomonay[2] — [1]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Kraków, Poland — [2]Institut für Physik, JGU Mainz, Germany

Magnetic vortices are topological spin structures commonly found in ferromagnets. However, they are novel for antiferromagnets. In particular, Wu et al. observed the interface-exchange-coupling-dependent transfer of the Fe vortex state to the coupled CoO or NiO layer for patterned microstructures [1]. We experimentally demonstrate that in a nanostructured antiferromagnetic-ferromagnetic hybrid bilayer, a magnetic vortex naturally stabilizes by magnetostatic interactions in the Fe(110) and imprints onto the adjacent NiO(111) via interface exchange coupling. We assume the coupling to be collinear, as recently reported in continuous NiO(111)-Fe(110) bilayers by Ślęzak et al. [2]. Our micromagnetic simulations elucidate the mechanism for the existence of antiferromagnetic vortex states [3]. We find that the interplay between the interface exchange coupling and the antiferromagnetic anisotropy plays a crucial role in locally reorienting the Néel vector out-of-plane in the prototypical in-plane antiferromagnet NiO and thereby stabilizing the vortices in the antiferromagnet. [1] Wu, J. et al. Nat. Phys. 7, 303-306 (2011). [2] Ślęzak, M. et al. Nanoscale 12, 18091-18095 (2020). [3] Ślęzak, M., Wagner, T. et al., in preparation.

MA 44.8 Thu 17:15 EB 301

Three-dimensional reconstruction, magnetization statics and dynamics in innovative curved nanoarchitectures. — •Jose A. Fernandez-Roldan[1], Olha Bezsmertna[1], Rui Xu[1], Oleksii M. Volkov[1], Oleksandr V. Pylypovskyi[1,2], Ondřej Wojewoda[3], Florian Kronast[4], Claas Abert[5], Dieter Suess[5], Michal Urbánek[3], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Kyiv Academic University,Ukraine — [3]CEITEC BUT, Brno University of Technology, Czech Republic — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [5]University of Vienna, Austria

Recent efforts have focused on exploring three-dimensional (3D) and curved magnetic nanostructures for nanoelectronics, sensorics, and computing, especially emphasizing spin textures and dynamics [1, 2]. However, studies on lattices of nanoarchitectures based on curved 3D elements are limited. Here we explore the properties of innovative, highly regular FeNi lattices of complex geometries [3]. A meticulous 3D reconstruction of the geometry coupled with modelling confirm that this system enables topologically non-trivial magnetic excitations in a high number. Dynamical measurements in combination with modelling confirm a switchable gap and local non-linear excitations. Overall, this system collects unique properties for becoming a captivating platform for advanced technologies in nanoelectronics and computing.

1. D. Makarov et al., Adv.Mater. 34(3), 2101758 (2022).
2. J. A. Fernandez-Roldan et al., APL Materials 10, 111101 (2022).
3. R. Xu, et al., Nat Commun 13, 2435 (2022).

MA 44.9 Thu 17:30 EB 301

Relativistic domain wall motion in ferrimagnets — •Pietro Diona — Scuola Normale Superiore di Pisa, Pisa, Italy — Italian Institute of Technology, Genova, Italy — ETH, Zurich, Switzerland

Domain walls in antiferromagnets are topological sine-Gordon solitons, characterized by relativistic kine- matics with the spin wave velocity setting a crucial limit for the operating speed of a magnetic racetrack memory. The relativistic kinematics of magnetic solitons was experimentally observed for the first time in crystalline ferrimagnets, but open questions on spin dynamics still remain. We aim to maximize the domain wall speed leveraging the tunability of amorphous alloys with rare-earth (RE) and transition-metal (TM) constituting two antiferromagnetic sublattices. By tuning RE concentration, it is possible to calibrate the anisotropy, the magnetization compensation point, and the net angular momentum compensation point, which are the keys to achieve high operating speeds in ferrimagnets. Here we extend the theoretical model describing the domain wall motion assisted by spin orbit torque and in-plane magnetic field [1] to the case of RE-TM systems, taking into account the phenomena of canting, domain wall width broadening and intrinsic pinning. It is proven that a domain wall in a RE-TM system can be described by a modified double sine-Gordon equation. The results are corroborated by magneto-optical

Kerr effect (MOKE) measurements of the domain wall motion.

[1]P. Diona et al., IEEE Trans. on Electron Devices, 69(7), 3675 (2022).

MA 45: Spin Structures and Magnetic Phase Transitions II

Time: Thursday 15:00–16:00 Location: EB 407

MA 45.1 Thu 15:00 EB 407

Modelling thermal transport in spiral magnets — •Margherita Parodi[1,2] and Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genova, Italy — [2]University of Genova, Italy

Magnetic memory and logic devices, including prospective ones based on skyrmions, inevitably produce heat. Thus, controlling heat flow is essential for their performance. Here we study magnon contribution to thermal conductivity in the most basic non-collinear magnet with a spin spiral ground state. Non-collinearity leads to anharmonic terms, resulting in magnon fusion and decay processes. These processes determine the magnon lifetime which can be used to estimate thermal conductivity in single mode approximation. However, by solving the full Boltzmann equation numerically, we find much higher thermal conductivity. This signifies that heat is carried not by individual magnons but by their linear combinations, called relaxons. The thermal conductivity is found to be increasing with the diminishing twist angle, consistent with recent experiments. The results pave the path to understanding magnetic thermal transport in other non-collinear magnets.

MA 45.2 Thu 15:15 EB 407

Optical conductivity in the kagome-based skyrmion-host material $Gd_3Ru_4Al_{12}$ — •Luca Malucelli[1], Felix Schilberth[1], Max Hirschberger[2], and István Kézsmárki[1] — [1]Experimentalphysik V, Center for Electronic Correlations and Magnetism, Institute for Physics, Augsburg University, D-86135 Augsburg, Germany — [2]RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan

Materials hosting topological magnetic textures, such as the atomic-scale skyrmion lattice in $Gd_3Ru_4Al_{12}$, attract great attention. In this itinerant magnet, the magnetic texture influences the electronic structure, leading to giant topological Hall Effect (THE) in the skyrmion lattice state of this compound. Motivated by this, we investigated the electronic structure of $Gd_3Ru_4Al_{12}$, with a breathing kagome lattice of Gd sites, by optical spectroscopy. In the talk, we discuss the main features of the optical conductivity spectrum arising from bands near the Fermi energy, with a special focus on changes of the optical properties upon the magnetic ordering taking place below 18 K.

MA 45.3 Thu 15:30 EB 407

Tuning Magnetism in Epitaxial $(Cr_{1-x}Mn_x)_2GaC$ MAX Phase Films: Insights into Stoichiometry and Chemical Disorder — •Ivan Tarasov, Hanna Pazniak, Olga Miroshkina, Michael Farle, and Ulf Wiedwald — University of Duisburg-Essen

MAX phases promise quasi-2D highly anisotropic magnetic properties due to their nanolaminated structure, tunable chemistry, and high oxidation resistance. Here, we study the $(Cr_{1-x}Mn_x)_2GaC$ MAX phase system with $0 \leq x \leq 1$ aiming to fine-tune magnetic responses through stoichiometric adjustments. High-quality epitaxial thin films (thickness 25 to 75 nm) are grown on rigid MgO(111), Al_2O_3(0001), and flexible muscovite $KAl_3Si_3O_{10}(OH)_2$(001) substrates by pulsed laser deposition. The structural characterization reveals a competition between $(Cr_{1-x}Mn_x)_2GaC$ MAX phase and competing phases, which is mitigated by optimizing the growth conditions. Vibrating sample magnetometry indicates an overall trend of increasing magnetization and ordering temperature with higher Mn content. The broad transition towards the paramagnetic phase within up to 150 K, however, for different $(Cr_{1-x}Mn_x)_2GaC$ MAX phase films are explained by local chemical order on M sites, as supported by first-principles calculations and Monte Carlo simulations within the Heisenberg model.

Acknowledgements

Funding by the Deutsche Forschungsgemeinschaft (DFG) within CRC/TRR 270, project B02 (Project-ID 405553726) is gratefully acknowledged.

MA 45.4 Thu 15:45 EB 407

Proton disorder in the double hydroxide perovskite $CuSn(OH)_6$ under hydrostatic pressure. — •Nikolai Pavlovskii[1], Anton Kulbakov[1], Kaushick Krishnakanta Parui[1], Darren C. Peets[1], Thomas Doert[2], Thomas Hansen[3], Ellen Häusler[2], Ines Puente-Orench[3], Vladimir Pomjakushin[4], and Dmytro S. Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]Anorg. Chemie II, TU Dresden, Germany — [3]ILL, France — [4]PSI, Switzerland

The understanding of proton disorder in materials beyond water ice is useful for the discovery of unique quantum phenomena. We present a comprehensive study of $CuSn(OH)_6$ (mineral name: mushistonite), a double hydroxide perovskite. Based on both X-ray and neutron diffraction studies, we have solved crystal structure of the synthetic deuterated compound $CuSn(OD)_6$ - *Pnnn*. At the same time, we have identified a strong disorder at all the deuterium sites. Furthermore, no magnetic Bragg peaks were found down to 50 mK, indicating that proton disorder may play a significant role in suppressing long-range magnetic ordering in this system, suggesting a ground state similar to that of a quantum spin liquid. It also motivates a pressure dependent investigation. Our experimental results reveal the structural nuances of $CuSn(OD)_6$ under varying pressures within a Paris-Edinburgh cell and shed light on potential structural phase transitions associated with proton ordering.

MA 46: Poster II

Time: Thursday 15:00–18:00 Location: Poster C

MA 46.1 Thu 15:00 Poster C

Interface driven emergent electromagnetic induction in $SrRuO_3/SrIrO_3$-bilayers — •Ludwig Scheuchenpflug[1], Robert Gruhl[1], Sebastian Esser[2], and Philipp Gegenwart[1] — [1]Experimentalphysik VI, Universität Augsburg, Germany — [2]Department of Applied Physics, University of Tokyo, Japan

Recently, emergent electromagnetic induction (EEMI), induced through current driven spin dynamics, was predicted [1] and later observed in the spin-helix magnet $Gd_3Ru_4Al_{12}$ [2] opening a new direction for material research and paving the way towards further miniaturisation of elements for electrical circuits.

Bilayers of ferromagnetic $SrRuO_3$ and paramagnetic $SrIrO_3$ display a topological Hall effect (THE) which was related to the formation of Néel-skyrmions arising from the Dzyaloshinskii-Moriya interaction at the interface [3,4]. Such skyrmions could also show the EEMI effect. We fabricated bilayers of $SrRuO_3/SrIrO_3$ on $SrTiO_3$ (001) substrates by metal-organic aerosol deposition and confirmed their quality with X-ray diffraction and TEM imaging. Besides Hall measurements, precise impedance measurements are analyzed at several temperatures and frequencies on a variety of microstructured samples.

[1] N. Nagaosa, Jpn. J. Appl. Phys. 58, 120909 (2019).
[2] Yokouchi et al., Nature 586, s41586-020-2775-x (2020).
[3] J. Matsuno et al., Science Adv. 2, e1600304 (2016).
[4] S. Esser et al., Phys. Rev. B 103, 214430 (2021).

MA 46.2 Thu 15:00 Poster C

Skyrmion flow in a periodically modulated channel — •Klaus Raab, Maurice Schmidt, Maarten A. Brems, Jan Rothörl, Fabian Kammerbauer, Peter Virnau, and Mathias Kläui — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We investigate the non-equilibrium flow behaviour of skyrmions, magnetic whirls with non-trivial real space topology, driven by spin-torques in modulated channel geometries. Poiseuille-like velocity flow-profiles of liquids usually occur due to no-slip boundary conditions, meaning moving particles do interfere with the boundary e.g. the wall of the confining geometry, reducing the velocity of particles closest to a wall1. Skyrmions on the other hand should experience slip at the boundaries due to the repulsive nature of the skyrmion-edge and skyrmion-skyrmion interaction. Adding structured obstacles along the boundary may lead to partial or even no-slip behaviour and thus to Poiseuille-like flow profiles while skyrmions are forced through a wire due to spin-torques. Influence of channel width and edge geometry modulation were optimized and tested using simulations and compared with experimental measurements of straight and modulated channels. Understanding flow dynamics and velocity profiles of skyrmions, their interaction with each other and their harbouring geometry is essential for skyrmionic applications like the racetrack memory2. 1. Sutera, S. P. & Skalak, R. The History of Poiseuille*s Law. Annu. Rev. Fluid Mech. 25, 1-20 (1993). 2. Fert, A., Cros, V. & Sampaio, J. Skyrmions on the track. Nat. Nanotechnol. 8, 152-156 (2013).

MA 46.3 Thu 15:00 Poster C

Manipulating magnetic textures with scanning local magnetic field — •Minh Duc Tran and Mathias Kläui — Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

We demonstrate local manipulation of magnetic textures in CoFeB/MgO multilayers based on the interaction between the sample and a customized magnetic force microscopy probe. By varying the scan height, write speed, number of scans, and specific magnetic coating of the tip, a tunable local stray field can induce desirable manipulation of the magnetic system. Complex topological textures such as skyrmions can be nucleated and manipulated individually, either by collapsing the stripe domains or cutting them into skyrmions with the aid of an external magnetic field [1]. Our results offer deterministic control of a skyrmion at a localized area, which can be beneficial, for instance, in future applications in skyrmion racetrack memory [2].

[1] A. V. Ognev et al., ACS Nano 14, 11, 14960-14970 (2020).
[2] A. Casiraghi et al., Commun. Phys. 2, 145 (2019).

MA 46.4 Thu 15:00 Poster C

Gesture recognition with Brownian reservoir computing using geometrically confined skyrmion dynamics — •Grischa Beneke[1], Thomas Brian Winkler[1], Klaus Raab[1], Maarten Brems[1], Fabian Kammerbauer[1], Johan Mentink[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Radboud University, Institute for Molecules and Materials, The Netherlands

Physical Reservoir Computing (RC) represents a significant advance for reducing the training time and energy consumption in nonconventional computing. It has been shown that magnetic skyrmions, topological particle-like spin textures, are promising candidates for unconventional computing [2,3] due to their non-linear interactions and efficient mechanisms for manipulation. Leveraging the thermally activated diffusive motion [2] and utilizing an automatic reset mechanism prompted by the repulsion of skyrmions from magnetic material boundaries has facilitated the realization of spatially multiplexed RC [3]. Here we take the next step and realize time-multiplexed RC. We present a hardware-based approach to distinguish various hand gestures captured via a Doppler radar, involving the application of a timevarying voltage to observe and track the trajectory of skyrmions. Notably, our device exhibits competitive performance when compared to an energy intensive approach [4]. [1] D. Gauthier et al., Nat. Comms. 12, 5564 (2021). [2] J. Zázvorka et al., Nat. Nanotechnol. 14, 658 (2019). [3] K. Raab et al., Nat. Comms. 13, 6982 (2022). [4] G. Beneke et al., in preparation (2023).

MA 46.5 Thu 15:00 Poster C

Direct observation of Néel-type skyrmions and domain walls in a ferrimagnetic DyCo3 thin film — •Chen Luo[1,2], Kai Chen[1,3], Victor Ukleev[1], Sebastian Wintz[1,4], Markus Weigand[1,4], Radu-Marius Abrudan[1], Karel Prokeš[1], and Florin Radu[1] — [1]Helmholtz-Zentrum-Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489, Berlin, Germany — [2]Institute of Experimental Physics of Functional Spin Systems, Technical University Munich, James-Franck-Straße 1, 85748, Garching b München, Germany — [3]National Synchrotron Radiation Laboratory, University of Science and Technology of China, 230029, Hefei, Anhui, China — [4]Max-Planck-Institut für Intelligente Systeme, 70569, Stuttgart, Germany

Isolated magnetic skyrmions are at the forefront of research interests due to their potential applications in information technology. A distinct class of skyrmion hosts are rare earth - transition metal (RE-TM) ferrimagnetic materials. We report on an ferrimagnetic material DyCo3 with a strong perpendicular anisotropy, the ferrimagnetic skyrmion size can be tuned by an external magnetic field. By taking advantage of the scanning transmission X-ray microscopy and utilizing a large x-ray magnetic linear dichroism contrast that occurs naturally at the RE resonant edges, we resolve the nature of the magnetic domain walls of ferrimagnetic skyrmions. We demonstrate that through this method one can easily discriminate between Bloch and Néel type domain walls for each individual skyrmion. For all isolated ferrimagnetic skyrmions, we observe that the domain walls are of Néel-type.

MA 46.6 Thu 15:00 Poster C

Chiral surface spin textures in Cu_2OSeO_3 unveiled by soft x-ray scattering in specular reflection geometry — •Victor Ukleev[1], Chen Luo[1], Radu Abrudan[1], Aisha Aqeel[2], Christian Back[2], and Florin Radu[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany

Resonant elastic soft x-ray magnetic scattering (XRMS) is a powerful tool to explore long-periodic spin textures in single crystals. However, due to the limited momentum transfer range imposed by long wavelengths of photons in the soft x-ray region, Bragg diffraction is restricted to crystals with the large lattice parameters. Alternatively, small angle x-ray scattering has been involved in the soft energy x-ray range which, however, brings in difficulties with the sample preparation that involves focused ion beam milling to thin down the crystal to below a few hundred nm thickness. We show how to circumvent these restrictions by using XRMS in specular reflection from a sub-nanometer smooth crystal surface. The method allows observing diffraction peaks from the helical and conical spin modulations at the surface of a Cu_2OSeO_3 single crystal and probing their corresponding chirality as contributions to the dichroic scattered intensity. The results suggest a promising way to carry out XRMS studies on plethora of noncentrosymmetric systems hitherto unexplored with soft x-rays due to the absence of the commensurate Bragg peaks in the available momentum transfer range [1]. [1] Ukleev, V., et al., Sci. Technol. Adv. Mater. 23, 683 (2022).

MA 46.7 Thu 15:00 Poster C

Coarse-Grained Computer Simulations of Skyrmions — •Simon Fröhlich, Jan Rothörl, Maarten A. Brems, Tobias Sparmann, Raphael Gruber, Mathias Kläui, and Peter Virnau — Institute of Physics, Johannes Gutenberg Universität, Mainz, Deutschland

Magnetic skyrmions are often described as 2D quasi-particles governed by the Thiele equation [1]. This abstraction allows for simulations of a large number of skyrmions on experimentally relevant time scales [2]. To accurately describe the experimental behavior, we determine an effective interaction potential [3] as well as a description of skyrmion pinning [4]. We will also discuss first ideas for matching experimental and simulation time scales to capture real dynamics in quasi-particle simulations.

[1] A. A. Thiele, Phys. Rev. Lett. 30, 230 (1973)
[2] J. Zázvorka et al., Adv. Funct. Mater, 30, 2004037 (2020)
[3] Y. Ge et al., Commun. Phys. 6, 30 (2023)
[4] R. Gruber et al., Nat. Commun. 13, 3144 (2022)

MA 46.8 Thu 15:00 Poster C

Magnetic anisotropy and anisotropic critical fields in MnSi and $Fe_{1-x}Co_xSi$ — •Gilles Gödecke, Julius Grefe, Stefan Süllow, and Dirk Menzel — Institut für Physik der Kondensierten Materie, TU Braunschweig, Mendelssohnstr.3, 38106 Braunschweig, Germany

The itinerant B20 bulk magnets MnSi and $Fe_{1-x}Co_xSi$ are known to host chiral spin structures and magnetic skyrmions arising from competing magnetic interactions including magnetic anisotropy. We report on the measurement of the magnetic anisotropy constants for MnSi and $Fe_{1-x}Co_xSi$ ($0.08 \leq x \leq 0.30$) using angle-resolved magnetisation measurements in a commercial SQUID magnetometer. From the measurements, we have identified the angle dependence of the critical fields H_{C1} and H_{C2}. Whereas both H_{C1} and H_{C2} for MnSi are maximal along the hard axis, the behavior of H_{C1} is opposite for $Fe_{1-x}Co_xSi$. The values of the anisotropy constants at $T = 5$ K are $K = -12 \times 10^2$ J/m^3 for MnSi and $K = (2...6) \times 10^2$ J/m^3 for $Fe_{1-x}Co_xSi$.

MA 46.9 Thu 15:00 Poster C

Determining pinning influence on skyrmion diffusion in 2D — •Tobias Sparmann, Simon Fröhlich, Jan Rothörl, Maarten A. Brems, Fabian Kammerbauer, Peter Virnau, and Mathias Kläui — Department of Physics, Johannes-Gutenberg University Mainz

Magnetic skyrmions are considered potential candidates for the development of probabilistic computing devices since they respond strongly nonlinearly to external stimuli and feature inherent multiscale dynamics [1].

The implementation of this type of probabilistic computing relies on thermal excitation and diffusive motion of the magnetic skyrmions within thin films, which exhibit pinning due to sample inhomogeneities [2]. To better understand the impact of pinning on larger scales, we need to model and understand the effective energy landscape of all areas the skyrmion can inhabit [3].

In this work, we investigate the spatial and temporal resolution limits we hit when determining the exact effective energy landscape, and we have a closer look at the specific characteristics of skyrmion diffusive motion. With this, we develop methods to overcome those limits and end up with a complete energetic model of skyrmion pinning and diffusion [4].

[1] D. Prychynenko et al., Phys. Rev. Applied, 9, 014034 (2018).
[2] J. Zázvorka et al., Nat. Nanotechnol., 14, 658 (2019).
[3] R. Gruber et al., Nat. Commun., 13, 3144 (2022).
[4] T. Sparmann et al., in preparation (2023).

MA 46.10 Thu 15:00 Poster C

Room Temperature Skyrmions in Pt/Co/Ta multilayers — Liz Montañez[1], Emmanuel Kentzinger[2], David Cortie[3], Valentin Ahrens[4], Laura Guasco[5], Thomas Keller[5], Markos Skoulatos[6], Markus Becherer[4], and •Sabine Pütter[1] — [1]FZ Jülich, Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]FZ Jülich, JCNS and Peter Grünberg Institut, JARA-FIT, Germany — [3]ARC Centre of Excellence in Future Low Energy Electronics Technologies and Institute for Superconducting and Electronic Materials, University of Wollongong, Australia — [4]Chair of Nano and Quantum Sensors, TU of Munich, Germany — [5]Max Planck Society Outstation at the MLZ, Garching, Germany — [6]MLZ and Physics Department, TU of Munich, Germany

Magnetic skyrmions are topologically stabilized spin configurations on the nanoscale. In magnetic multilayers, they can be stabilized at room temperature. Polycrystalline$[Pt(40Å)/Co(x)/Ta(19Å)]_N$ multilayers were fabricated in a molecular beam epitaxy setup by thermal deposition on oxidized Si(001) substrates with a Ta buffer layer and a Pt cap layer. The Co film thickness was varied between 5 Å and 21 Å and N varied between 8 and 10.

Magnetic force microscopy measurements reveal the existence of skyrmions at a Co thickness between 9 Å and 17 Å. We discuss results obtained from magnetic hysteresis, transport and neutron reflectometry measurements. The latter have been performed with the neutron reflectometer Platypus at ANSTO, Australia.

MA 46.11 Thu 15:00 Poster C

Skyrmion dynamics in the stripe domain phase — •Omer Fetai[1], Lisa-Marie Kern[2], Ross Knapman[1,3,4], Maike L. Auer[2], Bastian Pfau[2], and Karin Everschor-Sitte[1,4] — [1]TWIST Group, University of Duisburg-Essen, Duisburg, Germany — [2]Max-Born-Institut, Berlin, Germany — [3]Johannes Gutenberg University Mainz, Mainz, Germany — [4]Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Duisburg, Germany

The skyrmion Hall effect, which deflects skyrmions from the direction of the driving electric current, is a major challenge for racetrack-like applications. Guiding the skyrmion motion and suppressing the skyrmion Hall effect is possible by modifying the energy landscape of the skyrmion-carrying racetrack. This can, for example, be achieved by ion irradiation [1], where the material properties are engineered. Alternatively, skyrmions can be embedded in a stripe domain phase such that the magnetic texture itself induces tracks along which the skyrmions move straight [2-4]. We combine the ideas of skyrmions embedded in stripe domain phases with tailored properties and investigate the skyrmion dynamics under the influence of Spin-Orbit-Torques. [1] Kern et al., Nano Lett. 2022, 22, 10, 4028*4035 [2] Müller, et al. Phys. Rev. Lett. 119, 137201 (2017) [3] Knapman et al., J. Phys. D: Appl. Phys. 54 404003 (2021) [4] Song et al., arXiv:2212.08991 (2022)

MA 46.12 Thu 15:00 Poster C

Current driven skyrmion movement and their electrical detection in Ta/CoFeB/MgO — •Hauke Lars Heyen[1], Malte Römer-Stumm[2], Jakob Walowski[1], Christian Denker[1], Kornel Richter[2], Jeffrey McCord[2], and Markus Münzenberg[1] — [1]Institute for Physics, University Greifswald, Germany — [2]Institute for Materials Science, Nanoscale Magnetic Materials and Magnetic Domains, CAU Kiel, Germany

Magnetic skyrmions are two-dimensional topological protected round spin structures. They have a strong potential for application in future storage devices like the conceptual skyrmion race-track memory. Such an implementation requires fundamental control over the dynamics of skyrmion motion and reliable tools for their detection. Skyrmions can be generated in Ta/CoFeB/MgO layer stacks at room temperature. Nanosecond electric current pulses on the nanosecond scale enable relocating the skyrmions using current densities from 10^12 - 10^13 A/m^2. The dynamic trajectories hint at the skyrmion-Hall effect and superdiffusion. The skyrmion-Hall effect results from the skyrmion topology, and the superdiffusion occurs due to defects on the motion path. Magnetic tunnel junctions (MTJ) are a promising tool to detect small magnetization changes. The selected Ta/CoFeB/MgO material system allows integrating MTJs into skyrmion samples. However, this integration of MTJs remains challenging, even though they work fine independently.

MA 46.13 Thu 15:00 Poster C

Room-Temperature Skyrmions in Ir/Fe/Co/Pt Multilayers Coupled to Co/Pt Multilayers — •Joe Sunny, Timo Schmidt, Tamer Karaman, and Manfred Albrecht — Institute of Physics, University of Augsburg, D-86159 Augsburg, Germany

Magnetic skyrmions are topologically protected swirling magnetic spin structures which can be stabilized by Dzyalonshinskii-Moriya interactions (DMI). In recent years, considerable research efforts have been dedicated to stabilizing and manipulating skyrmions at room temperature in multilayer systems as these promise applications in skyrmion-based topological spintronics. The system studied combined of a skyrmion hosting multilayer of Ir/Fe/Co/Pt and a ferromagnetic layer of Co/Pt with perpendicular easy axis of magnetization separated by a non-magnetic spacer layer of Cu. The skyrmion layer hosts skyrmions of Néel-type stabilized by the interlayer DMI from the Ir/Fe and Co/Pt interfaces[1]. The magnetic domains formed in the skyrmion hosting layer are coupled to the ferromagnetic layer via the Cu spacer by Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction. From the Lorentz transmission electron microscope (LTEM) imaging the spin objects are observed to be not entirely Néel-type but also have a Bloch-type contrast. To study if the skyrmions from the underlying layer are completely imprinted onto the top Co/Pt layer, X-ray magnetic circular dichroism (XMCD) measurements were performed.

References

1.Anjan Soumyanarayanan et.al, Nature Mater 16, 898*904 (2017).

MA 46.14 Thu 15:00 Poster C

Engineering of Néel-type Skyrmions in Novel Freestanding Heterostructures — •Zihan Yin, Peng Wang, Ke Gu, Abhay Srivastava, and Stuart Parkin — Max Planck Institute of Microstructure Physics, Halle, Germany

Skyrmions are spatially inhomogeneous spin textures with nanoscale size. Néel-type skyrmions can be induced by interfacial symmetry broken. They are regarded as novel information carriers for use in high-density, low-power, and multi-functional spintronic devices. In this project, we use freestanding technology to tune the strain effects in ferromagnets. The phase of spin textures can be observed through Lorentz Transmission Electron Microscope (LTEM).

In this project, the wrinkles on the freestanding heterostructure thin film can result in various types of magnetic textures due to the varying strain. And with applied field, we can observe difference in density for both strip and skyrmion phase.

MA 46.15 Thu 15:00 Poster C

Skyrmion Stripes in Twisted Double Bilayer Graphene — •Debasmita Giri[1,2], Dibya Kanti Mukherjee[3,4], Herbert A. Fertig[4,5,6], and Arijit Kundu[2] — [1]University of Regensburg, Regensburg, Germany — [2]Department of Physics, Indian Institute of Technology Kanpur, Kanpur 208016, India — [3]Laboratoire de Physique des Solides, CNRS UMR 8502, Universitè Paris-Saclay, 91405 Orsay Cedex, France — [4]Department of Physics, Indiana University, Bloomington, IN 47405 — [5]Quantum Science and Engineering Center, Indiana University, Bloomington, IN, 47408 — [6]Instituto de Ciencia de Materiales de Madrid, (CSIC), Cantoblanco, 28049, Madrid, Spain

Two-dimensional moiré systems have recently emerged as a platform in which the interplay between topology and strong correlations of electrons play out in non-trivial ways. Among these systems, twisted double bilayer graphene (TDBG) is of particular interest as its topological properties may be tuned via both twist angle and applied perpendicular electric field. In this system, energy gaps are observed at the half-filling of particular bands, which can be associated with correlated spin-polarized states. In this work, we investigate the fate of these states as the system is doped away from this filling. We demonstrate that, for a broad range of fractional fillings, the resulting ground state is partially valley polarized and supports multiple broken symmetries, including a textured spin order indicative of skyrmions, with a novel stripe ordering that spontaneously breaks C3 symmetry.

MA 46.16 Thu 15:00 Poster C

Cavity-based excitation of Magnetization dynamics in a skyrmion host material — •Philipp Schwenke[1], Lars Hess[1], Ephraim Spindler[1], Aisha Aqeel[2], Vitaliy Vasyuchka[1], Christian Back[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany

Magnetic skyrmions are vortex-like topologically protected spin textures that typically occur in chiral magnets with Dzyaloshinskii-Moriya interactions. A prominent skyrmion host material is Cu_2OSeO_3. This crystal exhibits a skyrmion lattice phase near the Curie temperature [1] and a second skyrmion phase at low temperatures [2]. In addition, it has recently been shown that a heterostructure of this chiral magnet with a ferromagnet exhibits hybrid modes in its ferromagnetic resonance spectra [3]. We study magnetization dynamics in a Cu_2OSeO_3 crystal placed in a custom-designed loop-gap microwave cavity and compare the coupling of cavity photons to magnons in Cu_2OSeO_3 to the corresponding coupling between magnons in a $Y_3Fe_5O_{12}$ sphere and the same cavity.

[1] A. Aqeel *et. al*, Phys. Rev. B **103**, L100410 (2021)
[2] A. Chacon *et. al*, Nature Phys **14**, 936-941 (2018)
[3] C. Lüthi *et. al*, Appl. Phys. Lett. **122**, 012401 (2023)

MA 46.17 Thu 15:00 Poster C

Coherent X-ray imaging of Nanoscale spin textures in Ferrimagnetic Multilayers — Tamer Karaman[1], •Manas R. Patra[1,2], Timo Schmidt[1], Riccardo Battistelli[1,2], Christopher Klose[3], Bastian Pfau[3], Manfred Albrecht[1], and Felix Büttner[1,2] — [1]University of Augsburg, 86159 Augsburg, Germany — [2]Helmholtz-Zentrum Berlin, 14109 Berlin, Germany — [3]Max Born Institute, 12489 Berlin, Germany

Chiral rare-earth transition metal ferrimagnets, combining ferromagnetic and antiferromagnetic traits, offer various advantages, including bulk Néel-type Dzyaloshinskii-Moriya interaction (DMI), adjustable anisotropy, and minimal stray fields [1]. Achieving small and yet rapidly moving information-carrying topological spin textures is essential for in-memory and neuromorphic computing technologies [2,3]. This promises to realize high DMI in a thick, compensated material at room temperature. Here we present a coherent x-ray imaging study on Pt/Co/Dy multilayers, which reveals magnetic skyrmions of significant variations in both the size and contrast. While pinning explains size differences, variations in contrast suggest exciting possibilities, such as a 3D spin texture due to a vertical gradient of magnetic properties induced by Dy diffusion or the presence of sub-10-nm-diameter DMI-stabilized skyrmions. This high-resolution imaging holds the promise of uncovering novel physics in the field of nano-magnetism. References: 1. Büttner, F., et al., Sci. Rep. 8, 4464 (2018). 2. Caretta, L. et al., Nat. Nanotechnol. 13, 1154 (2018). 3. Fert, A., et al., Nat. Rev. Mater. 2, 17031 (2017).

MA 46.18 Thu 15:00 Poster C

Mössbauer spectroscopy on $CeFeSb_3$ — •Felix Seewald[1], Manuel Schulze[2], Thomas Doert[2], Michael Ruck[2], and Hans-Henning Klauss[1] — [1]Institut für Festkörper und Materialphysik, TU Dresden, Germany — [2]Fakultät für Chemie und Lebensmittelchemie, TU Dresden, Germany

Rare earth transition metal antimony systems exhibit a wide range of interesting magnetic properties. For example, in $R_3Fe_3Sb_7$ (R = Pr, Nd) we find a complex magnetic structure with R-Fe interplay[1].

The $CeFeSb_3$ structure consists of layers of iron centered $FeSb_2$ octahedera alternating with a Sb square lattice in between Ce layers. The Mössbauer spectrum at room temperature shows a single iron site exhibiting quadrupole splitting due to the presence of an electric field gradient (EFG). The center shift at room temperature is 0.469(3) mms^{-1} relative to α-iron with an EFG principle component of $V_{zz} = \pm 19.1(4)\,\mathrm{V\AA}^{-2}$.

Surprisingly even at 4.2 K no static magnetic hyperfine field is detected by Mössbauer, i.e. the spectrum still consists of a single quadrupole split iron site.

We will compare our findings with ferromagnetic order in other transition metal antimony systems.

[1] Falk Pabst, Sabrina Palazzese et. al., Advanced materials

MA 46.19 Thu 15:00 Poster C

Dilatometry studies on van der Waals ferromagnets $Fe_{3-\delta}GeTe_2$, CrI_3 and $Cr_2Ge_2Te_6$ — •Erik Walendy[1], Sven Sprachmann[1], Eva Brücher[2], Rheinhard Kremer[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

The van der Waals materials $Fe_{3-\delta}GeTe_2$, $Cr_2Ge_2Te_6$ and CrI_3 develop long-range ferromagnetic order down to the monolayer. In the bulk, long-range magnetic order appears at about 220 K, 65 K and 61 K respectively. Our high-resolution capacitance dilatometry studies imply significant magneto-elastic coupling as demonstrated by pronounced anomalies in thermal expansion and magnetostriction. We determine the uniaxial pressure dependencies of T_C and of the dominant energy scales by means of Grüneisen scaling. In $Cr_2Ge_2Te_6$, the magnetic phase diagram is determined and extremely large uniaxial pressure dependencies are observed. In CrI_3, in addition to the response of the ferromagnetic bulk phase, we find magnetostrictive signatures of the antiferromagnetic surface phase. The comparison of the three materials provides further insight into the relevance of spin-orbit coupling for the development of long-range magnetic order in quasi-2D van der Waals materials.

MA 46.20 Thu 15:00 Poster C

Multi-Q state emerging from frustrated interlayer exchange interaction — •Bjarne Beyer, Mara Gutzeit, Moritz A. Goerzen, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany

Superpositions of spin spirals, so-called multi-Q states, are complex spin structures which are of fundamental interest and promising for future spintronic applications. A prominent example is the triple-Q state predicted more than 20 years ago [1] and recently observed in ultrathin Mn films on surfaces [2,3]. Superposition states are energetically degenerate with the corresponding single-Q (spin spiral) states within the Heisenberg model, however, higher-order exchange interactions can lift this degeneracy [1]. Here we propose a three-dimensional multi-Q state in a Mn bilayer that is stabilised by frustrated interlayer exchange interactions. Our study combines ab initio calculations via density functional theory, atomistic spin simulations as well as Fourier analysis and simulation of spin-polarized scanning tunneling microscopy images.

[1] P. Kurz *et al.*, PRL **86**, 1106 (2001).
[2] J. Spethmann *et al.*, PRL **124**, 227203 (2020).
[3] F. Nickel *et al.*, PRB (in press) and arxiv:2307.09764 (2023).

MA 46.21 Thu 15:00 Poster C

The phenomenological model calculations for ultrafast magnetization dynamics — •Jav Davaasambuu, Tsednee Tsogbayar, and Odsuren Sarnai — Institute of Physics and Technology, MAS, Ulaanbaatar, Mongolia

We study ultrafast magnetization dynamics induced by laser heating using various phenomenological temperature models. In this work we have studied the two- and three-temperature models for nickel, iron and cobalt thin films. The temperature dynamics of the electrons, spins and lattice for thin films is investigated. From the 3TM calculation the magnetization dynamics of samples has been obtained as a function of spin temperature, while it is computed using the electron temperature in the 2TM calculation. It has been shown that demagnetization from the 3TM calculation can be clearly related to the increase of the spin temperature. For nickel, we have shown that our numerical result for magnetization is in good agreement with an experimental measurement.

MA 46.22 Thu 15:00 Poster C

Strain engineering of ferroic properties in $AFeO_3$ (A = La, Bi) films — •Antonia Rieche, Aurora Diana Rata, Wolfgang Hoppe, and Kathrin Dörr — Martin-Luther-Universität Halle-Wittenberg

Ferroic properties such as magnetization (M), antiferromagnetic order (L) and ferroelectric polarization (P) can be studied and potentially manipulated with light. An essential prerequisite for this is a successful control of the ferroic domain structures, so that a large mean value of M (L, P) can be achieved. Antiferromagnetic ferrites $AFeO_3$ with weak canted ferromagnetism have shown intriguing optical properties in bulk single crystal, while work on thin films is quite limited due to nanoscopic multidomain coexistence. Here we present results of our attempt to optimize $BiFeO_3$ and $LaFeO_3$ layers for optical experiments. The epitaxial strain controlled by the choice of substrate is used to achieve the formation of structural domains in these ferrite layers in a desirable way. Defined structural domain patterns allow selected orientations and sizes of M, L and P. The films are grown using pulsed laser deposition (KrF 248 nm) and characterized by x-ray diffraction, magnetooptical Kerr effect and scanning probe microscopies.

MA 46.23 Thu 15:00 Poster C

A theoretical study of new polar and magnetic double perovskites for photovoltaic applications — •Neda Rahmani[1], Alireza Shabani[2], and Jost Adam[3] — [1]Niels Bohr International Academy, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark — [2]Department of Electrical and Photonics Engineering, Photonic Nanotechnology, NanoPhoton, Technical University of Denmark (DTU), Copenhagen, Denmark — [3]Computational Materials and Photonics, Kassel University, Kassel, Germany

Searching for novel functional materials has attracted significant interest for the breakthrough in photovoltaics to tackle the prevalent energy crisis. Through density functional theory calculations, we evaluate the structural, electronic, magnetic, and optical properties of new double perovskites Sn2MnTaO6 and Sn2FeTaO6 for potential photovoltaic applications. Our structural optimizations reveal a non-centrosymmetric distorted triclinic structure for the compounds. Using total energy calculations, antiferromagnetic and ferromagnetic orderings are predicted as the magnetic ground states for Sn2MnTaO6 and Sn2FeTaO6, respectively. The empty d orbitals of Ta5+-3d0 and partially filled d orbitals of Mn/Fe are the origins of ferroelectricity and magnetism in these double perovskites resulting in the potential multiferroicity. The structural stability, suitable band gap, and high absorption coefficient values of proposed compounds suggest they could be good candidates for photovoltaic applications.

MA 46.24 Thu 15:00 Poster C

Electrically controlled magnetoeletric switching in a multiferroic — Sergey Artyukhin[2], Louis Ponet[2], Janek Wettstein[1], Alexey Shuvaev[1], Maxim Mostovoy[3], Andrei Pimenov[1], Anna Pimenov[1], and •Maksim Ryzhkov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria — [2]Quantum Materials Theory, Istituto Italiano di Tecnologia, Genova, Italy — [3]Zernike Institute for Advanced Materials, University of Groningen, Groningen, The Netherlands

Electric control of magnetism and magnetic control of ferroelectricity can improve the energy efficiency of magnetic memory and data-processing devices. However, the necessary magnetoelectric switching is hard to achieve, and requires more than just a coupling between the spin and the charge degrees of freedom. Recently, we showed that an application and subsequent removal of a magnetic field reverses the electric polarization of the multiferroic $GdMn_2O_5$, thus requiring two cycles to bring the system back to the original configuration. During this unusual hysteresis loop, four states with different magnetic configurations are visited by the system, with one half of all spins undergoing unidirectional full-circle rotation in increments of about 90 degrees. Our findings established a paradigm of topologically protected switching phenomena in ferroic materials.

Here I will present further study on electrically controlled magnetoelectric switching in the multiferroic $GdMn_2O_5$. We show that the sign of the resulting polarization can be precisely manipulated based on the direction of the electric field.

MA 46.25 Thu 15:00 Poster C

Sprayed nanometer-thick hard magnetic coatings with strong perpendicular anisotropy for data-storage applications — •A. Chumakov[1], C.J. Brett[1,2], K. Gordeyeva[2], D. Menzel[3], L.O.O. Akinsinde[4,5], M. Gensch[1], M. Schwartzkopf[1], W. Cao[6], S. Yin[6], M.A. Reus[6], M.A. Rübhausen[4], P. Müller-Buschbaum[6], L.D. Söderberg[2], and S.V. Roth[1,2] — [1]DESY, Hamburg, Germany — [2]KTH, Stockholm, Sweden — [3]Technische Universität Braunschweig, Braunschweig, Germany — [4]Universität Hamburg, Hamburg, Germany — [5]Kiel University, Kiel, Germany — [6]Technische Universität München, Garching, Germany

Ferromagnetic $SrFe_{12}O_{19}$ nanoparticles with a solid magnetic moment perpendicular to their plane and stabilized by a positive surface charge can form a self-ordered coating under the influence of magnetic fields drying from dispersion. We investigated the film formation of a stable colloid dispersion of ferromagnetic nanoplates and nanoblocks onto a silicon substrate and cellulose nanofilm without and under the action of an external magnetic field during scalable layer-by-layer spraying. The formation of a film of ferromagnetic particles from an aqueous colloid makes it possible to form a stable magnetic coating of agglomerates of nanoparticles with a fractal structure. An external magnetic field in the deposition process leads to the appearance of residual magnetization in the film. In this case, particles with a smaller aspect ratio (nanoblocks) form a periodic structure of agglomerates of nanoparticles with signs of an artificial opal-like structure.

MA 46.26 Thu 15:00 Poster C

Studying the electronic band structure of the exfoliated two-dimensional antiferromagnet $NiPS_3$ via temperature dependent μ-ARPES — Benjamin Pestka[1], •Biplab Bhattacharyya[1], Jeff Strasdas[1], Miłosz Rybak[2], Adi Harchol[3], Niklas Leuth[1], Honey Boban[4], Vitaliy Feyer[4], Iulia Cojocariu[4], Daniel Baranowski[4], Simone Mearini[4], Lutz Waldecker[1], Bernd

Beschoten[1], Christoph Stampfer[1], Marcus Liebmann[1], Lukasz Plucinski[4], Efrat Lifshitz[3], Magdalena Birowska[5], and Markus Morgenstern[1] — [1]RWTH-Aachen University, Germany — [2]Wrocław University of Science and Technology, Poland — [3]Technion - Israel Institute of Technology, Haifa, Israel — [4]Forschungszentrum Jülich, PGI-6, Germany — [5]University of Warsaw, Poland

Two-dimensional (2D) anti-ferromagnetic (AFM) materials offer novel research directions due to the pronounced interaction of electronic, spin and lattice structure. Transition metal phosphorus trisulfides ($TMPS_3$) are a semiconducting class of 2D AFM materials with intralayer AFM order. Till date, the role of the electronic band structure for AFM coupling in exfoliated thin flakes of $TMPS_3$ has often remained unexplored. Here, we present a comprehensive study of temperature dependent angle-resolved photoemission spectroscopy (ARPES) of the exfoliated few-layered $NiPS_3$ above and below the Néel temperature (T_N). We observe band spectra changes across T_N that are compared with density functional theory data to pinpoint their orbital character. The AFM transition in our exfoliated flakes has been verified by Raman spectroscopy.

MA 46.27 Thu 15:00 Poster C

Surface roughness optimization of 2D and 3D 2-Photon Polymerization Lithography templates and their influence on magnetic thin film properties — •Christian Janzen, Bhavadip Bharatbhai Rakholiya, Florian Ott, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

To experimentally investigate the impact of geometry and curvature on the properties of magnetic thin film systems, micron-sized slanted/curved structures were prepared by 2-photon polymerization (2PP) lithography. By systematically varying the 2PP process parameters, the root-mean-square roughness of 2D/3D shaped structures is minimized. Adding a Cu buffer layer, further smoothening of the surface was achieved, as atomic force microscopy measurements show. Elevating the structures with lithographically produced spacers allows us to investigate two scenarios for the deposition of a magnetic thin film on top of these structures: (1) the 2D/3D magnetic film is connected to surrounding flat film (no spacer) and (2) the 2D/3D magnetic film is isolated (with spacer). Therefore, it is possible to tune the exchange and dipolar interaction of 2D/3D microstructured magnetic thin films. The magnetic properties of a ferromagnetic thin film as a function of the surface roughness and shape anisotropy (i.e., the geometry of the templating structure) are investigated using magneto-optical Kerr microscopy.

MA 46.28 Thu 15:00 Poster C

Electron-phonon interaction, magnetic phase transition, charge density waves and resistive switching in VS2 and VSe2 revealed by Yanson PCS — Dmytro Bashlakov[1], •Oksana Kvitnitskaya[2,1], Saicharan Aswartham[2], Luminita Harnagea[3], Dmitri Efremov[2], Bernd Büchner[2,4], and Yuri Naidyuk[1] — [1]B. Verkin Institute for Low Temperature Physics & Engineering, NASU, Kharkiv, Ukraine — [2]Leibniz-Institute for Solid State Research, IFW Dresden, Dresden, Germany — [3]Dep. of Physics, Indian Institute of Science Education and Research, Pune, India — [4]Institute of Solid State and Materials Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, Dresden, Germany

The transition metals dichalcogenides VS2 and VSe2 possess promising properties as to magnetic and CDW ordering, emergent superconductivity, which are very sensitive to the stoichiometry and dimensionality. Yanson point-contact (PC) spectroscopic study reveals metallic and nonmetallic state in VS2 PCs, as well as magnetic phase transition below 25 K. PC spectra of VS2 testifies to the thermal regime, although the rare PC spectrum has a broad maximum at 20 mV due to electron-phonon interaction (EPI). PC spectra of VSe2 show metallic behavior with the features associated to EPI and CDW. The Kondo effect, which appeared for both compounds, is apparently due to interlayer V-ions. A resistive switching between a low-resistance metallic state and a high-resistance non-metallic state was observed in the PC on VSe2. The alteration of stoichiometry in PC core due to displacement of V-ions to interlayer under high electric field may be the reason.

MA 46.29 Thu 15:00 Poster C

Skyrmion dynamics in confined structures — •Thomas Brian Winkler[1], Jan Rothörl[1], Maarten Brems[1], Grischa Beneke[1], Hans Fangohr[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University, Staudinger Weg 7, 55128 Mainz, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter Hamburg, Luruper Chaussee 149, 22761 Hamburg

Magnetic skyrmions are fascinating spin structures from a physics perspective due to their topological stabilization but are also considered for next-generation non-conventional computing devices [1,2]. Skyrmions must be hosted in a finite-sized sample for a device application, and the dynamics can differ from those in continuous film geometries. We investigate the dynamics of a driven confined skyrmion ensemble and find different meta-stable states to occur [3].

[1] K. Everschor-Sitte et al., Journal of Applied Physics 124, 240901 (2018). [2] K. Raab et al., Nat Commun 13, 6982 (2022) [3] Thomas Brian Winkler et al., arxiv:2303.16472 (2023)

MA 46.30 Thu 15:00 Poster C

Characterizing the defocusing behaviour of magnetic microparticles for the application in three-dimensional trajectory tracking — •Nikolai Weidt, Yahya Shubbak, Rico Huhnstock, and Arno Ehresmann — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

To realise Lab-on-a-chip systems superparamagnetic particles (SPPs) can be surface-functionalized to bind specific analytes [1]. The directed transport of SPPs above magnetically stripe-patterned exchange bias layer systems is a promising approach to achieving analyte binding and transfer [2]. Precise analysis of three-dimensional SPP trajectories in this system can lead to the detection of analyte-binding events. To access the third dimension, the defocusing of particles moving out of the microscope's focal plane during transport steps is measured [3]. In this work, the quantization of defocusing is done by determining the Tenenbaum gradient (TG) of single particles. Using a calibration procedure, the z-coordinate of SPPs is derived from the measured TG. The obtained 3D trajectories are confirmed by numerical simulations for SPP motion. [1] Rampini, S., Li, P., Lee, G.U., 2016. Lab on a Chip 16, 3645*3663. [2] D. Holzinger, I. Koch, S. Burgard, and A.Ehresmann, ACS Nano 9, 7323 (2015) [3] Huhnstock, R., Reginka, M., Sonntag, C., Merkel, M., Dingel, K., Sick, B., Vogel, M., Ehresmann, A., Sci Rep 12, 20890.

MA 46.31 Thu 15:00 Poster C

Structural and magnetic characterization of FeOx nanoparticle dispersions upon freezing and melting — •Maximilian Enneking[1,2], Asmaa Qdemat[1], Martin Dulle[3], Rolf J. Haug[4], and Oleg Petracic[1,5] — [1]Jülich Centre for Neutron Science JCNS-2 und Peter Grünberg Institut PGI-4, Forschungszentrum Jülich GmbH — [2]Faculty of Mathematics and Physics, Leibniz Universität Hannover — [3]Jülich Centre for Neutron Science (JCNS-1), Forschungszentrum Jülich GmbH — [4]Institute of Solid State Physics, Leibniz Universität Hannover — [5]Heinrich Heine University Düsseldorf, Faculty of Mathematics and Natural Sciences, Düsseldorf

We have studied the structural and magnetic properties of magnetic nanoparticle dispersions upon cooling and heating over the solvent melting temperature. The particles consist of iron oxide dispersed in water or toluene with diameters ranging from 10 to 20 nm. The magnetic properties were studied using SQUID magnetometry employing zero field cooled (ZFC)/field cooled (FC) magnetization curves at different fields and hysteresis curves. To investigate the influence of temperature on the properties of nanoparticles and their assemblies, in situ SAXS measurements were performed at variable temperatures. We observe distinct freezing/melting signatures in magnetometry of the nanoparticle-solvent system depending on the particle size and the type of solvent.

MA 46.32 Thu 15:00 Poster C

Towards Recycling of Nd-Fe-B Permanent Magnets in a Circular Economy — •Aybike Paksoy[1], Amrita Khan[1], Abdullatif Durgun[1], Mario Schönfeldt[2], Hasan Mahmudul[2], Iliya Radulov[2], Imants Dirba[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Department of Materials and Geosciences, Functional Materials, Germany — [2]Fraunhofer IWKS, Fraunhofer Research Institution for Materials Recycling and Resource Strategies, Germany

Nd-Fe-B magnets have the highest room temperature energy product (BH)max and therefore are the material of choice in various application areas critical to the clean energy transition. However, usage of critical rare earth elements creates a number of environmental, economic as well as geopolitical concerns related to China which is the main global exporter. Exhaust gas and waste water are generated in significant amounts by the chemicals needed for the rare earth mining and refining processes. If not handled properly, it will have a huge impact on the environment, causing groundwater pollution and geological deterioration. This pollution affects humans as well in the circular ecosystem, and subsequent environmental governance comes at a heavy cost. Therefore, companies and researchers have been gradually focusing on the recycling of back-end waste Nd-Fe-B permanent magnets. For an environmentally friendly product, it is necessary to reduce the criticality and increase the sustainability of rare earth permanent magnets. In this study, we investigate advanced recycling processing towards sustainable Nd-Fe-B magnets without sacrificing the performance.

MA 46.33 Thu 15:00 Poster C

Effect of Zr and Cu alloying elements on microstructure and magnetic properties of Sm2Co17-type magnets — •B. Ekitli[1], A. Aubert[1], F. Maccari[1], N. Polin[2], X. Chen[2], E. Adabifiroozjaei[3], L. Molina-Luna[3], B. Gault[2], K. Skokov[1], and O. Gutfleisch[1] — [1]FM, TU Darmstadt, Germany — [2]MPIE, Düsseldorf, Germany — [3]AEM, TU Darmstadt, Germany

Hard magnetic properties of 2:17-type Sm(CobalFewCuyZrx)z magnets are mainly controlled by domain wall pinning. The complex microstructure including a superposition of 2:17 cells, 1:5 cell boundaries, and Zr-rich z-lamellae is essential for optimal performance [1]. In addition, the microchemistry is key for pinning through Cu gradient concentration and layers in the 1:5 cell boundaries [2]. Within this complex composition and microstructure, each element plays a distinct role in developing the desired phases and magnetic properties. In this study, we focus on studying the influence of Cu and Zr content in developing the microstructure and hard magnetic properties using simpler composition than commercial ones. A systematic study has been conducted using the Sm(CobalCuyZrx)z composition, excluding Fe, with the values x= 0.023 & 0.031, y= 0-0.30, and z= 6.7 & 7.7. Thus, we can reveal the individual role of Zr and Cu for optimum magnetic performance through detail analysis of the magnetic properties (hysteresis and domain structure observation) and correlate them with microstructure (SEM, TEM and APT). We acknowledge funding by CRC TRR 270 HoMMage. [1] Gutfleisch, O. (2009). DOI: 10.1007/978-0-387-85600-1_12 [2] S. Giron et al (2024)

MA 46.34 Thu 15:00 Poster C

Two-powder method for heavy rare earth reduced sintered NdFeB magnets — •Abdullatif Durgun[1], Konrad Opelt[2], Chi-Chia Lin[2], Jürgen Gassmann[2], Imants Dirba[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Department of Materials and Geosciences, Functional Materials, 64287 Darmstadt, Germany — [2]Fraunhofer IWKS, 63457 Hanau, Germany

Nd2Fe14B magnets play crucial role in e-motor technology, enhancing efficiency and power density. However, their use in high-temperature motors (up to 200 °C) is limited due to the low Curie temperature and decreased coercivity. As a result, NdFeB magnets require high coercivity (*2400 kA/m) at room temperature for effective operation in high-temperature e-motor applications. This can be achieved by replacing Nd atoms with heavy rare earths like Dy or Tb, however with significantly increased costs and reduced magnetization. Therefore, this study aims to improve the thermal stability and coercivity of sintered NdFeB magnets by forming (Nd,Dy/Tb)2Fe14B-rich shells around the Nd2Fe14B grains. Sintered NdFeB magnets were fabricated via our patented 2-powder-method [1,2] using NdFeB main phase and Dy/Tb-rich high-anisotropy powders. The impact of powder particle size, alloy composition and mixing ratios is systematically investigated to optimize the magnet microstructure and magnetic properties. Forming (Nd,Dy/Tb)2Fe14B shells around the NdFeB core boosts coercivity without significant magnetization loss, enabling the use of cost-and-resource-efficient and large volume NdFeB magnets at high temperatures.

MA 46.35 Thu 15:00 Poster C

Homogeneous permanent magnetic field for magnonic applications — •Gabriel Schwöbel, Vitaliy I. Vasyuchka, Aleksander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Universität Kaiserslautern Landau, 67663 Kaiserslautern, Germany

Our work addresses the development of a homogeneous permanent magnetic field experimental setup for a variety of applications, primarily in the field of magnonics. Particularly sensitive are spin-wave phase measurements, which require a high degree of homogeneity, as well as the minimisation of any noise that might be imposed by using an electromagnet.

The setup is inspired from a paper which includes two NeFeB permanent magnets, a soft magnetic yoke and pole shoes. The main goal is to figure out a suitable shape of the yoke and the pole shoes which provide a homogenious magnetic flux distribution over macroscopic distances (e.g. 10 mm) with. To achieve this goal, COMSOL Multiphysics was used to simulate the field strength distribution for different shapes of pole shoes.

We analysed different types of pole shoes to ensure improved homogeneity for different gap sizes. Since the required homogenity is approximately given by the line width of the spin wave excitations studied in yttrium-iron garnet, we looked for a value of around 50 μT in a 1 cm cube centred on the gap.

MA 46.36 Thu 15:00 Poster C

Insights into the electronic structure of Ce-substituted permanent magnets — •Benedikt Eggert[1], Alex Aubert[2], Fabrice Wilhelm[3], Andrei Rogalev[3], Konstantin Skokov[2], Heiko Wende[1], Oliver Gutfleisch[2], and Katharina Ollefs[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Functional Materials, Technical University of Darmstadt — [3]European Synchrotron Radiation Facility

Permanent magnets significantly contribute to renewable energy technologies based on their broad range of potential applications [1]. The relatively low abundance of rare-earth elements such as Nd and Sm motivates additional research into cost-effective hard magnetic materials by replacing Nd or Sm with more abundant rare-earth materials, such as Ce, Pr or La. With this contribution, we investigate the magnetic properties of Ce-substituted Nd-Fe-B [2] or Ce-Co permanent magnets utilizing X-ray absorption spectroscopy and X-ray magnetic circular dichroism. We will correlate how the system's magnetic properties depend on Ce's valence state.

We acknowledge the financial support through the Deutsche Forschungsgemeinschaft within the framework of the CRC/TRR270 HoMMage (Project 405553726-TRR270), the BMBF (05K2019 and 05K2022), and we thank the ESRF for allocation of beamtime at the beamline ID12 within project HC-4051.

[1] O. Gutfleisch et al. Adv. Mater. 23, 821-842 (2011)
[2] Y. Wu et al. Acta Materialia, 235, 118062 (2022)

MA 46.37 Thu 15:00 Poster C

Magnetic Interaction in the Frustrated Dimer Magnet $Cs_3Fe_2Br_9$ — •Felix Wirth[1], Sebastian Biesenkamp[1], Alexandre Bertin[1], Dimitry Gorkov[1], Ivan Sidis[2], Jakob Lass[3], Rafal Wawrzynczak[3], Petra Becker-Bohatý[4], Ladislav Bohatý[4], and Markus Braden[1] — [1]II. Physic. Inst., Univ. Cologne, Germany — [2]LLB, CEA Saclay, France — [3]SINQ, PSI Villigen, Switzerland — [4]Inst. Geology a. Mineralogie, Univ. Cologne, Germany

The frustrated magnet $Cs_3Fe_2Br_9$ with Fe_2Br_9 bioctahedron dimers in a triangular lattice exhibits a remarkable variety of magnetic phases, when magnetic fields are applied along the c-axis and huge magnetoelastic anomalies [1]. In addition, there are magnetization plateaus for H||c, while magnetization for H||a,b stays linear up to saturation [1]. Here we present additional neutron scattering experiments to further elucidate the character of magnetic correlations. While at low temperature and zero field, magnetic order is commensurate with parallel moments in a dimer, a competing phase is incommensurate. Inelastic neutron scattering studies on the multiplexing spectrometer CAMEA determined the dispersion of magnons in the ordered phase over a wide range of Q space. The results were analyzed by linear spin-wave calculations with *SpinW* yielding a rather 3D character of the magnetism. However, low-energy magnon response in the ordered state as well as the diffuse and quasielastic scattering in the intermediate and paramagnetic phases are smeared over large parts on the Brillouin zone boundary, further characterizing this system as a peculiar frustrated magnet. [1] D. Brüning, et al. Phys. Rev. B. 104 (2021).

MA 46.38 Thu 15:00 Poster C

Indications of dynamical magnetism in magnetically ordered Kagome metals
— •Sheetal Devi[1], Yishui Zhou[1], Min-Kai Lee[2], Lieh-Jeng Chang[2], Hubertus Luetkens[3], Zurab Guguchia[3], and Yixi Su[1] — [1]Jülich Centre for Neutron Science JCNS at Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Jülich GmbH, Lichtenbergstraße 1, D-85747 Garching, Germany

— [2]Department of Physics, National Cheng Kung University, Taiwan 70101, Taiwan
— [3]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232, Villigen PSI, Switzerland

We have investigated the low-temperature physical properties of topological intermetallic compounds RV_6Sn_6 (R = Tb, Dy, Ho, Er) using heat-capacity and muon spin relaxation (μSR) measurements. These compounds feature a combination of a V-based nonmagnetic Kagome sublattice and an R-based magnetic triangular sublattice that harbors different spin anisotropies for different R ions. Long-range magnetic order is seen for R = Tb, Dy, Ho, and Er compounds at 4.3, 3.0, 2.4, and 0.6 K, respectively. However, the hyperfine analysis of the heat capacity data yields a reduced value of magnetic moment for all the compounds, implying persistence spin fluctuations down to 50 mK. Indications of such dynamical magnetism are further supported by our μSR studies. We argue that this intriguing competition and coexistence between persistent spin dynamics and long-range magnetic order is a manifestation of strong magnetic frustration in these systems.

MA 46.39 Thu 15:00 Poster C

Single-crystal-diffraction studies on the iron-superconductor parent compounds LaFeAsO and SmFeAsO — •Akshay Tewari[1], Felix Anger[2], Alexandre Bertin[1], Bernd Büchner[2], Sabine Wurmehl[2], and Markus Braden[1] — [1]II. Phys. Inst., Univ. Cologne, Germany — [2]IFW, Dresden, Germany

Iron-based superconductors exhibit a complex interplay between structure, magnetism and superconductivity. Here, we report detailed X-ray diffraction single-crystal structure analyses on the *1111* family of FeAs superconductors REFeAsO, where RE is La or Sm. Previous powder neutron diffraction measurements on LaFeAsO revealed tiny structural anomalies occurring around the structural and magnetic transitions.

The crystal structure is tetragonal at room temperature, and a structural transition occurs at 160-170 K into the orthorhombic phase. In the tetragonal phase we observe reflections violating the h+k=2n condition at low (hk0) values. These peaks are attributed to multiple diffraction arising from the high crystal quality. Below the structural transition, the appearance of orthorhombic domains reduces the crystal quality and thus multiple diffraction. We find no evidence for additional scattering centers (or residual electron density) in the unit cell. Structural anomalies observed for the Fe-As distance and FeAs layer thickness around the transition temperature tend to agree with previous measurements performed using powder data [1]. Anharmonic refinements (up to 4th order) indicate non-harmonic distributions appearing around the La and As atoms near the transition temperatures.

MA 46.40 Thu 15:00 Poster C

Thermodynamic properties of the checkerboard model of altermagnet — •Kostiantyn Yershov[1,2], Volodymyr Kravchuk[1,2], and Jeroen van den Brink[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine

Using the checkerboard Hubbard hamiltonian as a model for two-dimensional altermagnet, we demonstrated that the temperature-induced fluctuations can lead to several new effects, namely the fluctuation induced piezomagnetism and thermal spin conductivity. First, computing the dispersion relation for magnons, we demonstrated that the model under consideration breaks the spin degeneracy in the momentum space leading to the anisotropic splitting of magnon branches typical for the altermagnets. Next, in the limit of low temperatures we considered the thermally induced magnons as an ideal Bose gas and computed the thermodynamic potential accordingly. Using the thermodynamic potential, we computed magnetization M as a thermodynamic quantity, and demonstrated that M vanishes for vanishing magnetic field. However, M is finite beyond the altermagnetic limit, when the diagonal terms in the checkerboard model becomes not equivalent, e.g. due to the applied mechanical stress. In addition, we predict generation of the spin-current in the response to the applied temperature gradients. We calculated the tensor of thermal spin conductivity, which is linear with diagonal terms of checkerboard model for small temperatures.

MA 46.41 Thu 15:00 Poster C

Magnetism in ultrathin quantum spin liquid Na_2IrO_3 flakes — •Deepak Roy and Mukul Kabir — Department of Physics, IISER Pune - 411008, India

Quantum spin liquids have attracted significant attention due to their complex physics arising from the interplay among the lattice geometry, spin-orbit coupling, and electron correlation. The Ir^{4+} oxides and Ru^{3+} chlorides possessing a honeycomb $j_{\text{eff}} = 1/2$ lattice are the primary candidate materials, which eventually exhibit long-range ordering at low temperatures. Using first-principles calculations, we explore ultrathin Na_2IrO_3 flakes to find that the zigzag antiferromagnetic ground state persists up to the monolayer. Magnetic ordering is investigated using appropriate Kitaev-Heisenberg Monte Carlo simulations. Surprisingly, the magnetic state is reinforced, and the monolayer is driven away from the Kitaev spin liquid state due to stronger Heisenberg and off-diagonal exchange interactions. In contrast, the charge-doped flakes undergo a Mott insulator-to-metal transition, and the flakes become ferromagnetic. These results illustrate exciting prospects for understanding magnetism in ultrathin non-van der Waals correlated oxides and their prospect in spin devices.

MA 46.42 Thu 15:00 Poster C

Magnetic phase diagram of Kitaev Quantum Spin Liquid candidate $Na_3Co_2SbO_6$ — •Kranthi Kumar Bestha[1,2], Manaswini Sahoo[1,2], Ryan Christopher Morrow[1], Andrey Maljuk[1], Bernd Büchner[1,2], Laura Teresa Corredor Bohorquez[1], and Anja U. B. Wolter[1] — [1]Institute for Solid State Research, Leibniz IFW Dresden 01069, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, 01062 Dresden, Germany

The quest for exotic Quantum Spin Liquids (QSL) with the most entangled quantum states, particularly in Kitaev Quantum Spin Liquid candidates, has posed significant challenges in the last two decades. The presence of non-Kitaev interactions has been a primary obstacle, as they destabilize the QSL ground state. To overcome this hurdle, a search for candidates with more localized d-orbitals, such as $3d$ cobaltates, was proposed, aiming to eliminate non-Kitaev interactions despite their weak spin-orbit interaction. In this study, we employed thermodynamic methods to characterize such a cobaltate KQSL candidate, $Na_3Co_2SbO_6$ (NCSO). Our investigations, including $M(H,T)$ and $C_p(T)$ studies on high quality single crystals, confirm AFM order in NCSO at $T_N = 7$ K. Our $M(T)$ data reveal that NCSO is an easy-plane magnet with large anisotropy in ab-plane and two metamagnetic transitions, manifestation of field-induced phases in the ordered phase. From the $M(H)$, $M(T)$ and $C_p(T)$ data we mapped out the magnetic phase diagram of NCSO in the light of theoretical predictions.

MA 46.43 Thu 15:00 Poster C

Field induce transition and quantum criticality in spin-$\frac{3}{2}$ stacked-honeycomb antiferromagnet: $Ba_2Co(PO_4)_2$ — •Aditi Agrawal[1], Koushik Chakraborty[1], Isha Isha[1], K. M. Ranjith[2], M. Baenitz[2], M. Isobe[3], A. K. Bera[4], and Arvind Kumar Yogi[1] — [1]UGC-DAE Consortium for Scientific Research, University Campus, Khandwa Road, Indore 452001, India — [2]Khandwa Road — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [4]Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai 400085, India

We report the bulk and local probe studies on $Ba_2Co(PO_4)_2$ with stacked-honeycomb lattices of cobalt ions on the bc-plane. Through a combination of magnetic susceptibility, specific heat, and ^{31}P NMR studies, the temperature-magnetic-field phase diagram associated with this long range magnetic ordering $T_N = 3$ K has been mapped out. A low-temperature field-induced spin-flop transition and spin-reorientation transition below T_N is found to occur at an applied field of $\sim$3 Tesla and $\sim$10 Tesla respectively. The temperature dependent susceptibility curve $\chi(T)$ also shows pronounced broad peak, characteristics of the short-range magnetic ordering, with $T_{max} = 4$ K. The combined results of heat capacity and susceptibility of $Ba_2Co(PO_4)_2$ stabilize a magnetic field induce phase transition. Interestingly, the quantum critical point (QCP) of the phase transition is determined from the extrapolation of the behaviour of T_N as a function of magnetic field on H-T phase diagram. The extrapolated QCP is found at a upper critical field ($H_C \sim 6.5\ T$

MA 46.44 Thu 15:00 Poster C

Magnetic properties of the spin-1/2 zigzag chain lattice antiferromagnet: $CaCuV_2O_7$ — •Koushik Chakraborty[1], Aditi Agrawal[1], Isha Isha[1], Suman Karmakar[1], R. Rawat[1], M. Isobe[2], and Arvind Kumar Yogi[1] — [1]UGC-DAE Consortium for Scientific Research, University Campus, Khandwa Road, Indore-452001, India — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

We report the magnetic properties of a new CuO_4 plaquette spin-1/2 zigzag chain compound $CaCuV_2O_7$, which ordered antiferromagnetically (AFM) below $T_N = 2.4$ K, and it reveals the $3d$ characteristics of a nearly divalent Cu^{2+} ion moment obtained from our Curie-Weiss (CW) magnetic susceptibility analysis. The effective magnetic moment $\mu_{\rm eff}$ is calculated to be 1.83 (2) $\mu_{\rm B}$, which is in good agreement with the Cu^{2+} ions for a $S = \frac{1}{2}$ and a g value of 2 (free-electron g-value). The negative Weiss constant $\theta_{\rm CW}$ = -18.9 K, as found to be from susceptibility CW fit, suggests that the dominant interactions between Cu^{+2} ions are of AFM. Interestingly, it is also found that the application of the applied magnetic field at H = 9T suppresses the magnetic ordering.

MA 46.45 Thu 15:00 Poster C

Interplay of electronic and lattice-mediated interactions in low-temperature orders of Ba2MgReO6 — •Dario Fiore Mosca[1,2], Cesare Franchini[3,4], and Leonid V. Pourovskii[1,2] — [1]Centre de Physique Theorique, Ecole Polytechnique, Paris, France — [2]College de France, Paris, France — [3]University of Vienna, Vienna, Austria — [4]University of Bologna, Bologna, Italy

The synergetic interaction of electron correlations and strong spin-orbit coupling can lead to the development magnetic and charge orders of high-rank multipoles. In this context, double perovskites with 5d1 electronic configuration offer a opportunity for investigating such phenomena, especially for realizing "hidden" quadrupolar phases.

In our study, we combine several ab-initio techniques that include DFT, DMFT, Jahn-Teller and phonon analysis as well as calculations of intersite exchange interactions using a many-body force-theorem method. This multifaceted approach successfully reproduces the double-step transition observed in Ba2MgReO6; namely, the formation of a higher-temperature anti-ferro quadrupolar phase followed by the onset of a canted anti-ferromagnetic state.

Our analysis reveals that those phases emerge from a complex interplay between the electronic superexchange mechanism and electron-lattice interactions. Additionally, our study clarifies the evolution of the low-temperature order under pressure, in particular, revealing a strong impact of non-hydrostatic pressure condition on the phase stability of Ba2MgReO6.

MA 46.46 Thu 15:00 Poster C

Growth, characterization and neutron scattering studies of $Sr_xCa_{1-x}RuO_3$ ($x = 0.5, 0.7$) single crystals — •Zahrasadat Ghazinezhad[1], Akshay Tewari[1], Karin Schmalzl[2,3], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln, Köln, Germany — [2]Jülich Centre for Neutron Science, Jülich, Germany — [3]Institut Laue-Langevin, Grenoble, France

The ferromagnetic order in $SrRuO_3$ attracts strong interest due to the impact of Weyl points on the magneto transport and on the spin dynamics, see [1]. Substituting Sr with isovalent Ca ion reduces the ferromagnetic transition temperature and completely suppresses the ferromagnetism state around 70 percent Ca doping. The smaller Ca ion causes enhanced octahedron tilting, which decreases the FM interaction and seems to imply antiferromagnetic interaction. The comprehensive studies of the spin-wave dispersion in $SrRuO_3$ already indicate some AFM interaction [1]. We grew large single-crystals of $Sr_xCa_{1-x}RuO_3$ ($x = 0.5, 0.7$) by the floating-zone technique. Inelastic neutron scattering studies were performed for both concentrations on the cold triple-axis spectrometer IN12 at the ILL. While $SrRuO_3$ exhibits the expected parabolic dispersion starting at a well defined anisotropy gap, both mixed materials show rather unusual magnetic response in the ordered phase. In spite of the reduced Curie temperatures the anisotropy gap seems to be strongly enhanced and even splits. Furthermore, there is finite scattering at the ferromagnetic zone center even below these gap values.

[1] K. Jenni, et al. , Phys. Rev. B 107, 174429 (2023).

MA 46.47 Thu 15:00 Poster C

Crystal structure and magnetic excitations of Sr4Ru3O10 — Zahrasadat Ghazinezhad[1], •Lara Kiefer[1], Augustinus Agung Nugroho[2], Paul Steffens[3], Ursula Bengaard Hansen[3], and Markus Braden[1] — [1]II. Physic. Inst., Univ. Cologne, Germany — [2]Institut Teknologi Bandung, Indonesia — [3]ILL, Grenoble, France

Large single-crystals of the triple layer ruthenate $Sr_4Ru_3O_{10}$ were grown by the floating zone technique in a mirror image furnace and characterized by X-ray diffraction, magnetization and resistance measurements. Comprehensive single-crystal X-ray diffraction studies reveal that the spacegroup is orthorhombic *Bbcm* and not *Pbam*, mostly used to describe the structure of $Sr_4Ru_3O_{10}$ [1]. RuO_6 octahedra are rotated around the axis perpendicular to the layers, but there is no additional tilting. The onset of ferromagnetic order at 105 K and the low-temperature ordered moment of 1.3 μ_B agree with earlier reports. The magnon dispersion was studied on the triple-axis spectrometers IN20 and Thales at the ILL. We find a parabolic isotropic dispersion with a stiffness constant that is comparable to that observed in the 3D material $SrRuO_3$ [2]. However, the detailed distribution of spin-wave scattering at low constant energy transfer deviates from the simple isotropic ring expected in the most simple model and the stiffness tends to increase upon heating again resembling the behavior in $SrRuO_3$ [2]. The spin-wave gap exhibits a rather anomalous temperature dependency with a strong increase upon cooling below 60 K.

[1] M. K. Crawford *et al.*, Phys. Rev. B **65**, 214412 (2002).
[2] K. Jenni *et al.*, Phys. Rev. Lett. **123**, 017202 (2019).

MA 46.48 Thu 15:00 Poster C

Disentangling the ferrimagnetic moment arrangement in the Ti-doped Barium hexaferrite using EMCD — •Hitoshi Makino[1], Rolf Erni[2], Bernd Rellinghaus[1], and Darius Pohl[1] — [1]DCN, cfaed, TUD Dresden University of Technology, Germany — [2]Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendolf, Switzerland

Barium hexaferrite is a well-known ferrimagnetic material with good durability at high temperatures and in erosive environments. Previous research has indicated that small Ti substitutions can enhance the coercivity at elevated temperatures. Our efforts aim at elucidating the underlying mechanism through measurements of electron energy loss magnetic chiral dichroism (EMCD), the electron analog to XMCD. We have deconvolved the Fe L-edges as obtained from classical EMCD measurements into different oxidation states of iron and estimated the influence of Ti substitution on the magnetic moments on each iron site. From this analysis, we identified that Ti2+ is substituted to the 4f2 site where Fe has an antiparallel magnetic moment in the Fe2+ octahedral oxidation state. However, EMCD signal of Fe2+ indicate parallel magnetic moment. EMCD measurements utilizing electron vortex beams (EVBs) in an aberration-corrected STEM hold the promise of achieving atomically resolved mappings of the magnetic moment. However, low signal-to-noise ratios (SNRs) currently impede atomic resolution in such measurements. Therefore, we have conducted EVB-EMCD measurements at the atomic scale using a direct detection camera. The impact on the method and achievable resolution will be discussed.

MA 46.49 Thu 15:00 Poster C

Size effect of the first-order magnetostructural transition in Ni-Mn-Sn — •Johannes Puy[1], David Koch[1], Enrico Bruder[1], Heiner Gutte[2], Volodymyr Baran[3], Konrad Opelt[1,4], Franziska Scheibel[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Darmstadt, Germany — [2]TU Bergakademie Freiberg, Freiberg, Germany — [3]DESY P02.1, Hamburg, Germany — [4]Fraunhofer IWKS, Hanau, Germany

Ni-Mn-Sn Heusler alloys exhibit a first-order magnetostructural transition (FOMST) and a large magnetocaloric effect. The FOMST is driven by a nucleation and growth mechanism. A size dependence of the FOMST can be observed in powder. However, conventional milling induces defects despite annealing, so the defect and size dependencies are difficult to disentangle. In this study, spherical, gas-atomized, and homogenized Ni-Mn-Sn powders with different size fractions are used to investigate the size dependence of the FOMST. Magnetic, structural, and microstructural analyses show a decrease in transition width and an increase in thermal hysteresis with decreasing particle size. Temperature-dependent magnetometry on single particles shows a sharp, jump-like FOMST for particles below 50 μm, while a continuous FOMST is observed for particles above 50 μm. Temperature-dependent X-ray diffraction shows a complete FOMST for all size fractions. Electron backscatter diffraction shows an average grain size of 20 μm for all particles. Therefore, the size dependence of FOMST can be correlated with the single- and polycrystalline nature of the particles. We thank the CRC/TRR 270 "HoMMage" for funding.

MA 46.50 Thu 15:00 Poster C

Hybrid simulation tracing non-equlibrium spin-dynamics — •Lukas Jonda, Johan Briones, Sebastian T. Weber, Christopher Seibel, Sanjay Ashok, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern

We simulate the interplay of several non-equilibrium phenomena arising in a magnetic film after femtosecond laser irradiation using a hybrid model. This approach consists of a combination of two methods: the μT model [1] and a kinetic Monte Carlo method [2]. The former treats the low-energetic electrons as ensembles, tracing spin-resolved temperatures and chemical potentials, as well as their gradients [3]. The latter traces the dynamics of individual high energetic non-equilibrium electrons, including spin-dependent scattering processes and a spin-flip probabilities. A model that can describe the transport of both the electronic ensemble and individual high-energy super-diffusive electrons is currently being developed. This allows the study of different types of non-equilibrium transport and their effects on magnetization dynamics.

References:
[1] B.Y. Mueller and B. Rethfeld, Phys. Rev. B, 90, 144420 (2014).
[2] J. Briones et al., J. Phys, 6, 035001 (2022).
[3] S. Ashok et al., App. Phys. Lett. 120, 142402 (2022).

MA 46.51 Thu 15:00 Poster C

Changes of the spin-spin and spin-lattice interaction induced by a ultrashort laser pulse — •Sergiy Mankovsky, Svitlana Polesya, and Hubert Ebert — Dept. Chemistry, LMU Munich, Butenandtstr. 11, D-81377 Munich, Germany

Ultrafast demagnetization implies complex dynamics concerning the electron, spin, and lattice degrees of freedom, coupled to each other and all being out-of-equilibrium after the laser pulse. The pure electron dynamics induced by a ultrashort laser pulse is well described within the time-dependent density functional theory (TD-DFT). However, spin and lattice excitations as well as interactions between all degrees of freedom are usually described making use of model Hamiltonians. The evolution of the spin system described using the Landau-Lifshitz-Gilbert equations is determined by the torque on the magnetic moments, stemming from different types of interactions entering the spin and spin-lattice Hamiltonian. The corresponding interaction parameters are determined by the electronic structure and can be calculated on a first-principles level. This implies that they should change together with the laser induced changes of the electronic structure. We will discuss the possible impact of such changes on the demagnetization dynamics, focusing on the isotropic exchange and different types of spin-lattice interactions. Their calculations have been performed employing TD-DFT potentials and occupation numbers generated by the Elk code [http://elk.sourceforge.net] for different time steps during the laser pulse and shortly after it. As is demonstrated for various systems, a strong modification of the parameters is found.

MA 46.52 Thu 15:00 Poster C

Static magnetic properties of ferromagnetic iron-nickel alloys in the Stoner model — •Sevim Kilic, Christopher Seibel, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

In a previous work by Hofherr *et al.* [1], the direct, ultrafast and coherent spin transfer between subsystems of iron-nickel (NiFe) alloys through optical excitation (OISTR effect) was experimentally demonstrated. For this purpose, the spin-resolved density of states (DOS), which is essential for explaining the OISTR effect, was directly calculated using density functional theory (DFT). Now, we want to understand how well these spin-resolved DOS and their exchange splittings can be approximated with shifted paramagnetic density of states in the framework of the Stoner model.

Our research involves the investigation of paramagnetic density of states in NiFe alloys, which were determined by weighted averaging of pure iron and nickel DOS. The self-determined DOS were compared to DFT-calculated DOS of NiFe alloys from literature [2]. We then analyze the magnetization resulting from the application of the Stoner model to both model assumptions and compare it to the magnetization of Permalloy obtained from DFT calculations [3].

[1] M. Hofherr *et al.*, Sci. Adv. 6, 8717 (2020)
[2] http://compmat.org/electron-phonon-coupling/
[3] S. Sharma, MBI Berlin, private communication (2023)

MA 46.53 Thu 15:00 Poster C

Magnetization-dependent electronic structure and ultrafast electron dynamics in CrGeTe3 — •Túlio de Castro[1], Tommaso Pincelli[2], Lawson Lloyd[1], Maciej Dendzik[1], Shuo Dong[1], Samuel Beaulieu[1], Ralph Ernstorfer[2], and Laurenz Rettig[1] — [1]Fritz-Haber-Intitüt, Berlin — [2]Technische Universität, Berlin.

2D magnets present new possibilities to develop sizable and versatile nanodevices that work by manipulating the spin current, making it more efficient than charge-based devices. One of these promising 2D magnets is $CrGeTe_3$ (CGT) with a Curie temperature of $\approx$ 65K. Besides the magnetic order, the dimensionality allows us to study heterostructures with other 2D materials and make use of magnetic proximity effects. Here, we study bulk crystals of CGT using angle-resolved photoemission spectroscopy (ARPES) and femtosecond time-resolved ARPES (trARPES) to understand the magnetic-order induced changes to the electron distribution and the exchange splitting dynamics at different temperatures. By comparing data at the ASTRID synchrotron with data from our trARPES setup, we discuss the temperature-dependent band structure modifications and their ultrafast dynamics in bulk CGT. We further discuss the implication of our results for thin layers, monolayers, and heterostructures.

MA 46.54 Thu 15:00 Poster C

Magnetic order-dependent ultrafast magnetization dynamics in 4f-based intermetallics — •Abeer Arora[1], Yoav Will Windsor[5], Sang-Eun Lee[1], Daniela Zahn[1], Victoria Taylor[1], Hyein Jung[1], Túlio de Castro[1], Kristin Kliemt[2], Ch. Schüssler- Langeheine[3], Niko Pontius[3], Cornelius Krellner[2], Denis V. Vyalikh[4], and Laurenz Rettig[1] — [1]FHI der MPG, Berlin — [2]Phy. Inst., Goethe-Uni., Frankfurt am Main — [3]HZB für Materialien und Energie, Berlin — [4]DIPC, Basque, Spain — [5]IOAP, TU Berlin

The speed of magnetic devices is limited by the dissipation channels available for Angular Momentum Transfer (AMT). While demagnetization in ferromagnets (FMs) requires AMT to the lattice or spin transport, antiferromagnets (AFMs) offer potentially faster demagnetization through inter-sublattice AMT. Owing to the limited understanding of such channels, especially in 4f-based Lanthanides, we study the ultrafast magnetization dynamics in the $LnTm_2Si_2$ series of intermetallics (with Ln=Lanthanide, Tm=transition metal), with similar crystal structure and RKKY-mediated magnetic orders. We employ time-resolved resonant soft X-ray diffraction (trRXD) to study AFM compounds ($GdTm_2Si_2$, Tm=Co, Rh, Ir, $EuRh_2Si_2$), and trXMCD on Eu based FMs ($EuRu_2P_2$, $EuFe_2P_2$). The Gd series reveals a scaling of AMT rate with the 5d spin polarization of the conduction electrons, underscoring conduction electrons as an extra tuning parameter for Ln-based devices. Furthermore, a comparison of the AFM dynamics with Eu-FMs provides information about the AMT to the lattice.

MA 46.55 Thu 15:00 Poster C

Influence of transport mechanisms and film thickness on ultrafast magnetization dynamics and generation of spin-resolved charge currents — •Sanjay Ashok, Christopher Seibel, Sebastian T. Weber, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau

Generation of spin-resolved charge-currents and pure spin-currents in sub-picosecond timescales are pertinent to understand and employ ultrafast transport phenomena in spintronic device concepts. In this work we study the influence of transport mechanisms and film thickness on ultrafast magnetization dynamics using the thermodynamic μT model [1]. We also study the generation of spin-resolved charge currents as well as pure-spin currents in metallic ferromagnets.

We seperately simulate the influence of thermal-conductivity, electrical-conductivity, Seebeck effect and Peltier effect on ultrafast magnetization dynamics. We then study spin-resolved charge-currents and pure spin-currents at various depths of the material. We compare their relative magnitudes in Nickel films with various thicknesses.

Our simulations provide a framework to study the relative roles of various transport mechanisms in generation of ultrafast currents.

[1] Ashok et al. APL, 120 142402 (2022)

MA 46.56 Thu 15:00 Poster C

udkm1Dsim - A Python toolbox for simulating 1D ultrafast dynamics in condensed matter — •Daniel Schick — Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany

The udkm1Dsim toolbox is a collection of Python classes and routines to simulate the thermal, structural, and magnetic dynamics after laser excitation, as well as the corresponding light-scattering response in stratified (1D) samples, such as multilayers. The toolbox provides the capabilities to define arbitrary layered structures on the atomic level including a rich database of element-specific physical properties. The excitation of dynamics is represented by an N-temperature model which is commonly applied in ultrafast physics. Structural dynamics due to thermal stresses are calculated by a linear-chain model of masses and springs. Magnetic dynamics can be calculated by a Landau-Lifschitz-Bloch or microscopic 3-temperature model. The resulting light-scattering response is computed by kinematical or dynamical X-ray theory which can also include polarization-dependent magnetic scattering. The udkm1Dsim toolbox is highly modular and allows for injecting user-defined inputs at any step within the simulation procedure.

MA 46.57 Thu 15:00 Poster C

The signature of 4f multiplet excitations to the M_5/M_4 branching ratio in Terbium and their influence on magnetization dynamics — •Beyza Salantur[1], Tim Amrhein[1], Niko Pontius[2], Christian Schuessler-Langeheine[2], Martin Weinelt[1], and Nele Thielemann-Kuehn[1] — [1]Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Str. 15, 12489 Berlin, Germany

In 4*f*-rare earth metals, magnetic order is established by intra- and interatomic exchange between 4*f* and 5*d* spins. We show that upon ultrafast optical excitation of the 5*d* electrons inelastic 5*d*-4*f* electron-electron scattering can alter the 4*f* orbital state and therewith the total angular momentum *J* [1]. This directly affects magneto crystalline anisotropy and has important implications for magnetization dynamics. Within a time-resolved X-ray absorption study at the FemtoSpeX slicing facility of BESSY II (HZB) we found transient changes of the M_5/M_4 branching ratio in Terbium, indicative of multiplet excitations changing *J* [2].

[1] N. Thielemann-Kühn et al., *Optical control of 4f orbital state in rare-earth metals.* https://doi.org/10.48550/arXiv.2106.09999 (Science Advances, in revision)

[2] B. T. Thole and G. van der Laan., *Branching ratio in x-ray absorption spectroscopy.* Phys. Rev. B, 38:3158-3171, Aug 1988.

MA 46.58 Thu 15:00 Poster C

Differentiating mechanisms that drive ultrafast magnetization precession — •Fried-Conrad Weber[1], Jasmin Jarecki[2], Max Mattern[1], Alexander von Reppert[1], and Matias Bargheer[1,3] — [1]Institute of Physics and Astronomy, University of Potsdam — [2]Max-Born-Institute, Berlin — [3]Helmholtz-Zentrum, Berlin

We study the influence of strain and heat on the ultrafast magnetization precession in Cobalt and Nickel. To achieve this, we combine trMOKE measurement of various samples under different initial conditions, with numerical simulations. We model the ultrafast dynamics of heat and strain in laser-excited thin films and the magnetization precession that is triggered by the concomitant time-dependent effective fields. In this way, we aim at understanding and controlling the complex interplay of heat, strain and magnetization dynamics.

MA 46.59 Thu 15:00 Poster C

Theoretical study of optical excitation effects in RuO_2 — •Luca Haag[1], Marius Weber[1], Kai Leckron[1], Stephan Wust[1], Benjamin Stadtmüller[1], Libor Šmejkal[2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67633 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

We study theoretically the optical response of the d-wave altermagnet RuO2. As an altermagnetic material RuO2 shows a momentum-dependent spin polarization in reciprocal space without net magnetization [1,2]. We investigate in particular how the underlying symmetries affect its optical characteristics. We employ a hybrid approach that combines Density Functional Theory (DFT) and optical transition probabilities in a Fermi's Golden Rule approach [3] to simulate the excitation with momentum, spin and band resolution.

[1] L. Šmejkal et al., Phys. Rev. X 12, 040501 (2022)

[2] L. Šmejkal et al., Phys. Rev. X 12, 011028 (2022)

[3] S. Essert and H. C. Schneider, Phys. Rev. B. 84, 224405 (2011)

MA 46.60 Thu 15:00 Poster C

Studying all-optical magnetization switching of GdFe by double-pulse laser excitation — Rahil Hosseinifar[1], Ivar Kumberg[1], Felix Steinbach[2], •Sangeeta Thakur[1], Sebastien E. Hadjadj[1], Jendrik Gördes[1], Mario Fix[3], Josè Miguel Lendìnez[4], Chowdhury Awsaf[1], Manfred Albrecht[3], Florian Kronast[5], Unai Atxitia[4], Clemens von Korff Schmising[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born Straße 2A, 12489 Berlin, Germany — [3]Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany — [4]Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, 28049 Madrid, Spain — [5]Helmholtz-Zentrum Berlin, Albert-Einstein-Straße 15, 12489 Berlin, Germany

We performed double-pulse experiments on a $Gd_{26}Fe_{74}$ ferrimagnetic alloy with a magnetic compensation temperature of about 120 K by x-ray magnetic circular dichroism photoelectron emission and optical Kerr microscopy. We demonstrate the effects of different ratios of fluence between two single laser pulses of 800 nm wavelength and a duration of 120 and 250 fs, at 70 K and at room temperature. We identified a time delay between 3 and 20 ps at which all-optical switching is suppressed. Atomistic spin dynamics (ASD) simulations have been carried out to describe the non-equilibrium dynamics following the excitation. They successfully describe the behaviour of the switching as a function of laser fluences and time delay between the two pulses.

MA 46.61 Thu 15:00 Poster C

Magnetic State Control of Non-van der Waals 2D Materials by Hydrogenation — •Tom Barnowsky[1,2], Stefano Curtarolo[3], Arkady V. Krashenninikov[2,4], Thomas Heine[1,2], and Rico Friedrich[1,2,3] — [1]TU Dresden — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [3]Duke University, Durham, USA — [4]Aalto University, Aalto, Finland

Controlling the magnetic state of 2D materials is a key enabler for spintronics. Especially in the novel class of non-van der Waals 2D compounds – materials derived from non-layered bulk counterparts – promising (surface) magnetic properties were outlined in recent years [1,2]. Utilising data-mining and autonomous density functional theory calculations, we demonstrate the modification of magnetic properties of these materials by hydrogen passivation [3]. The magnetic configurations are tuned to states with flipped and enhanced moments, which we rationalize by analysing Bader charges. For 2D $CdTiO_3$ – a diamagnetic compound in the pristine case – we observe an onset of ferromagnetism upon hydrogenation. Further investigation of the magnetization density in both pristine and passivated systems provides a detailed analysis of modified local spin symmetries and the emergence of ferromagnetism. Our results suggest that selective surface passivation is a powerful tool for tailoring magnetic properties of nanomaterials, such as non-vdW 2D compounds.

[1] R. Friedrich *et al.*, Nano Lett. **22**, 989 (2022).

[2] T. Barnowsky *et al.*, Adv. Electron. Mater. **9**, 2201112 (2023).

[3] T. Barnowsky *et al.*, submitted, arXiv:2310.07329 (2023).

MA 46.62 Thu 15:00 Poster C

Interfacial Engineering of ultrafast dynamics in 2d ferromagnets — •Nele Stetzuhn[1,2], Clemens von Korff Schmising[2], Nikola Nedeljkovic[1], Stefan Eisebitt[2], and Kirill I. Bolotin[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Max-Born-Insitut, Max-Born-Straße 2A, 12489 Berlin

The clean and atomically sharp interfaces of 2d materials offer a convenient way to manipulate their properties by introducing, e.g., screening, external fields or doping. In this work, we investigate whether it is possible to influence de- and remagnetization dynamics in the 2d ferromagnet Fe3GeTe2 by varying its substrate between hBN and graphene, as well as suspending it over a cavity. Differences in recovery times of up to a factor 10 have been estimated from simulations between a supported and a suspended device. We test this theoretical prediction using time- and spatially resolved Kerr microscopy.

MA 46.63 Thu 15:00 Poster C

Classification of complex 2D magnetic ground states using unsupervised Contrastive Learning — Jannis Neuhaus-Steinmetz[1], •Tim Matthies[1], Elena Y. Vedmedenko[1], Thore Posske[2], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, Hamburg, Germany — [2]I. Institute for Theoretical Physics, University of Hamburg, Hamburg, Germany

Phase diagrams capture the essential features of a system in many areas of physics. Distinguishing one phase from another is often done by hand-crafted selection rules and an automated approach could accelerate this process. Here, we use a machine learning technique called contrastive learning to classify 18,000 magnetic ground state configurations into 12 distinct clusters. This is done by using a hybrid approach of increasing the number of clusters given by the model to 40 and then merging these clusters into the 12 phases by hand. The ground states of two-dimensional magnetic atomic lattices on metallic substrates are generated by fitting a tight-binding model to a classical Heisenberg model and subsequent classical Monte Carlo calculations. The symmetries of the system are utilized as transformations to cluster identical phases together. Furthermore, we investigate the representation space created by the model as a quick overview for understanding large amounts of physical data. The approach contributes to a better understanding of the connection between magnetism and topological electronic matter. Our results are generalizable to other systems in condensed matter physics and beyond.

MA 46.64 Thu 15:00 Poster C

Implementation of spin-torque exchange-correlation functionals in VASP for noncollinear magnetism — •Fabien Tran, Marie-Therese Huebsch, and Martijn Marsman — VASP Software GmbH, Vienna, Austria

The implementation in VASP of an exchange-correlation functional for noncollinear magnetism is reported. It is the functional developed by Tancogne-Dejean, Rubio and Ullrich [Phys. Rev. B **107**, 165111 (2023)], based on the idea of Pittalis, Vignale and Eich [Phys. Rev. B **96**, 035141 (2017)]. The functional is of the meta-GGA type since it depends on the kinetic-energy density and Laplacian of the density. However, it also depends on the paramagnetic current density and, furthermore, on the full 2×2 spin density matrix, therefore leading to a non-zero exchange-correlation spin torque. The results of calculations on noncollinear systems (e.g. bulk Mn_3Sn and the Cr_3 molecule) are reported and compared to results obtained with standard functionals, e.g. PBE and SCAN.

MA 46.65 Thu 15:00 Poster C

Ferromagnetic resonance simulations of arranged magnetic nanoparticles — •Felix Schug[1,2], Nils Neugebauer[2,3], Michael Czerner[1,2], and Christian Heiliger[1,2] — [1]Institute for Theoretical Physics, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Center for Materials Research (LaMa), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [3]Institute of Experimental Physics I, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Magnetic nanoparticles (MNPs) are utilized in a variety of electronic applications due to their unique magnetic characteristics. *Mesocrystals*, composed of arranged MNPs, offer additional degrees of freedom to manipulate these magnetic characteristics. Understanding the magnetic properties of mesocrystals is crucial for optimizing their use in applications. In this study, we used the publically available micromagnetic simulation tool OOMMF, to investigate mesocrystals composed of magnetite MNPs. We arranged the mesocrystals on a periodic grid with varying inter-mesocrystal distances by employing two-dimensional periodic boundary conditions. Our simulations of ferromagnetic resonance (FMR) spectra revealed various resonance frequencies. A spatially resolved analysis was conducted to investigate the origins of these frequencies within the mesocrystal.

MA 46.66 Thu 15:00 Poster C

An Ab Initio Study of Monolayer Mn2Mg2X5 (X = S, Se), a Novel Family of 2D Half-Metallic Ferromagnets — •Soheil Ershadrad and Biplab Sanyal — Uppsala Univeristy, Uppsala, Sweden

Based on first principle calculations, we propose a family of stable 2D ferromagnets, Mn2Mg2X5 (X = S, Se), with a half-metallic electronic structure. They possess a high Curie temperature, and strong magnetocrystalline anisotropy. An indirect exchange interaction, mediated by chalcogen atoms, dominates in these crystals. Their half-metallicity and high-temperature magnetism render them suitable candidates for spintronic applications.

MA 46.67 Thu 15:00 Poster C

Hopf index calculation in micromagnetic finite-element simulations — •Louis Gallard[1], Karin Everschor-Sitte[2], and Riccardo Hertel[1] — [1]Université de Strasbourg and CNRS, IPCMS, 67000 Strasbourg, France — [2]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany

Magnetic Hopfions are complex topological textures that can be regarded as three-dimensional (3D) counterparts of skyrmions. They have recently attracted considerable interest due to their intriguing structure and possible use in spintronic devices. Unlike skyrmions, which are usually easy to spot in magnetic configurations, Hopfions are difficult to identify because of their complex knotted 3D vector field distribution. The difficulty arises even in micromagnetic simulations, where detailed information about the magnetic structure is readily available. The Hopf index, a topological invariant, provides a measure of Hopfions that allows for their quantitative detection. However, in the general case of 3D samples of finite size, calculating the Hopf index usually involves a two-fold volume integral, whose $\mathcal{O}(N^2)$ scaling makes its evaluation impracticable in large-scale computations. Here, we present an alternative approach which involves solving a partial differential equation by using a hybrid finite-element / boundary-element method. We retain a scaling of nearly $\mathcal{O}(N)$, which is suitable for high-performance computing. The method is fast enough to be used during dynamic micromagnetic simulations to monitor the Hopf index's evolution in time. We demonstrate the application of the method to a Hopfion structure in a cylinder and a torus geometry.

MA 46.68 Thu 15:00 Poster C

The effectiveness of spin injection from bulk Nickel into phosphorene — •Puja Kumari and Soumya Jyoti Ray — Indian Institute of Technology Patna, Bihar, India, 801106

The moderate electronic band gap and larger carrier mobility of 2D phosphorene, make it a promising candidate for future nanoelectronics. With the addition of magnetism to black phosphorene, its applications will be greatly expanded, as well as creating the possibility to design new spintronic devices. Here employing first-principles calculations, we investigate the efficiency of spin transmission from a ferromagnetic electrode (Ni) into phosphorene (P/Ni(111)). Additionally, enhance the spin injection efficiency (SIE) by replacing a single phosphorene layer with bi- and tri-layers of phosphorene. Twist engineering allows us to moderate the SIE up to 60%. To begin with, we systematically studied the structural, electronic, and magnetic properties of the P/Ni(111) junction including bi- and tri-layers of phosphorene. The mono-, bi-, and tri- layers of phosphorene on the Ni surface exhibit metallic properties upon establishing ohmic contact, demonstrating a proximity effect. After that, we have done a detailed analysis of the transport property of spin carriers with negative differential resistance. The findings of our study provide new insights into the design of phosphorene-specific spin devices.

MA 46.69 Thu 15:00 Poster C

Ab-initio spin dynamics in non-collinear magnets — •David Eilmsteiner[1,2], Pawel Buczek[2], and Arthur Ernst[1] — [1]Johannes Kepler University, Linz, Austria — [2]HAW Hamburg, Hamburg, Germany

The investigation of magnetization dynamics is a highly active field of research on both the experimental and the theoretical side. Our group focuses on the determination of magnetic properties by means of the Korringa-Kohn-Rostoker Green's functions approach to density functional theory. This method not only allows for the self-consistent determination of ground state properties of ordered and disordered materials, it can also conveniently be extended to the description of magnetization dynamics in the linear response regime, which allows for the investigation of various magnetic excitations, such as Stoner excitations or magnons on an equal footing.

On my poster, I will focus on our current effort to extend our method to non-collinear magnetic systems. Investigating the dynamics of non-collinear magnets, stabilized either by geometric frustration or relativistic effects, is of great interest as, in that case, the magnetization dynamics are no longer decoupled from charge density oscillations. Furthermore, the spin-flip excitations are not decoupled from the longitudinal magnetization dynamics. These effects open additional decay channels for spin dynamics, which are absent in the collinear case.

MA 46.70 Thu 15:00 Poster C

An iterative approach for the coupling of surface acoustic waves to micromagnetics — •Michael Karl Steinbauer[1], Peter Flauger[1], Bernhard Emhofer[1], Matthias Küss[2], Stephan Maximilian Glamsch[2], Matthias Volz[3], Hubert Krenner[3], Manfred Albrecht[2], and Claas Abert[1] — [1]University of Vienna — [2]University of Augsburg — [3]University of Münster

In recent years, the coupling of magnetic and phononic systems has emerged as a rapidly developing field of study. As these interactions usually happen with a resonance frequency in the GHz regime, it has a variety of possible industrial applications [1].

In many experimental publications, a macro-spin model has been used to simulate the influence of surface acoustic waves (SAWs) onto the magnetic system. [2]. However, this approach is not capable of accurately predicting the magnetization dynamics in systems with spatially varying magnetization patterns such as magnetic domains.

In this work, we present a micromagnetic model, which is able to simulate these interactions using an extension of the magnum.np python library [3]. Additionally, we introduce an iterative algorithm to predict the decay of the SAW amplitude as it travels along a magnetic structure.

[1] P. Delsing et al., J. Phys. D: Appl. Phys. 52, 353001 (2019).
[2] M. Küß et al., Phys. Rev. Appl. 15, 034046 (2021).
[3] F. Bruckner et al., Sci. Rep. 13, 12054 (2023).

MA 46.71 Thu 15:00 Poster C

Origin of Magnetism in monolayer VI3 — •Anita Francis and Swapan Pati — JNCASR, Bengaluru, India

We have studied the magnetic properties of monolayer VI3 from first principles. Using the generalised Heisenberg model we have calculated the isotropic and anisotropic exchange parameters for the system, which we then have used in a Monte Carlo simulation to predict the ordering temperature in the system. We observe that the system orders ferromagnetically at a temperature around 50K.

MA 46.72 Thu 15:00 Poster C

Antiferromagnetically coupled half-shell magnetite nanoparticles with tuneable magnetic remanence — •Patrick Steinkraus[1], Inci Nur-Sahin[1], Veronica Salguerino[2], Ecem Tiryak[2], Marina Spasova[1], and Michael Farle[1] — [1]Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, 47057 Germany — [2]Departamento de Física Aplicada and CINBIO, Universidade de Vigo, 36310 Vigo, Spain

Magnetite nano-hybrids were chemically synthesized in the form of two magnetite half-shells with a length of 460 nm and width of 90 nm covered with a 30 nm thick silicon dioxide layer. Structure, chemical composition, and morphology were characterized using Transmission Electron Microscopy, Energy Dispersive X-Ray Spectroscopy and Electron Energy Loss Spectroscopy. The magnetic hysteresis of individual particles was simulated using data from our structural and morphological analysis. In the absence of magnetic field, the composite particle acts like an antiferromagnet. However, when exposed to an external magnetic field of B = 75mT, the magnetizations of the two half-shells align ferromagnetically. Below B = -34mT, the magnetizations revert to their antiparallel alignment. The 30 nm thick silica shell suppresses the dipole-dipole interaction between particles preventing their agglomeration. These properties may make these nanoparticles perfect candidates for magneto-mechanical and hyperthermia therapies. Funding by the European Union's Horizon 2020, project No 857502 (MaNaCa) is gratefully acknowledged.

MA 46.73 Thu 15:00 Poster C

Quantum Tunneling of Magnetization in Tilted Toroidal Systems — •Jonas Waltenberg and Jürgen Schnack — Bielefeld University

Molecular magnets with a toroidal arrangement of the easy anisotropy axes are often viewed as promising candidates for magnetic storage and quantum computing [1,2]. For this a high stability against perturbations like external magnetic fields is needed. As a measure of this stability the tunneling matrix elements for spin systems of different sizes with easy anisotropy axes tilted from the collinear arrangement to the toroidal arrangement are calculated. It is discussed which systems are stable against this quantum tunneling of magnetization.

[1] D. Pister, K. Irländer, D. Westerbeck, J. Schnack, Toroidal magnetic molecules stripped to their basics, Phys. Rev. Research 4 (2022) 033221

[2] K. Irländer, J. Schnack, Studies of decoherence in strongly anisotropic spin triangles with toroidal or general non-collinear easy axes, Phys. Rev. Research 5 (2023) 013192

MA 46.74 Thu 15:00 Poster C

A study of magnetic properties of face-sharing 3d manganese trimers — •Anzar Ali[1,2], Sungkyun Choi[1], and Masahiko Isobe[2] — [1]Sungkyunkwan University, Suwon 16419, Republic of Korea — [2]Max Planck Institute for Solid State Research, Stuttgart Germany 70569

The emergence of a potentially conflicting molecular orbital state in correlated electron systems has recently garnered substantial attention in condensed matter physics, presenting a promising arena for uncovering novel electronic phases. Although this state has predominantly been explored in 4d and 5d transition metal oxides due to their extended orbital nature, our investigation focuses on 3d transition metal-based compounds featuring a face-sharing trimer. This study unveils systematic findings and a comprehensive understanding of two new 3d hexagonal perovskites, Ba4TaMn3O12 and Ba4NbMn3O12, wherein a face-sharing Mn trimer along the c-axis interacts within the hexagonal lattice. Surprisingly, effective magnetic moments suggest an S=2 trimer, while magnetic entropies propose a localized S=3/2 trimer. This apparent contrast finds resolution in a partial molecular orbital state, combining antiferromagnetically localized moments (S=3/2) and a delocalized one-electron (S=1/2) state within the trimer.

Ab-initio calculations reveal itinerant electron sharing and AF ordering in a Mn trimer, resulting in a unique coexistence of localized and delocalized electron states in a 3d material. To eliminate powder limitations, we stress the importance of growing single crystals using floating zone techniques to address disorder and impurity phases.

MA 46.75 Thu 15:00 Poster C

Probing spin-orbit coupling at hybrid single-molecule magnet/metal interfaces — •David Anthofer[1], Ashish Moharana[1], Dominik Laible[2], Fabian Kammerbauer[1], Eva Rentschler[2], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg Universität Mainz, 55128 Mainz, Deutschland — [2]Department Chemie, Johannes-Gutenberg Universität Mainz, 55128 Mainz, Deutschland

Single-molecule magnets have recently gained significant interest for their ability to retain magnetic information at the molecular level, surpassing the superparamagnetic limit of conventional magnetic storage technologies and offering potential applications in ultra-compact and high-density data storage devices. A crucial challenge hindering their application in technology is the integration with thin-film devices. To master this challenge, we explore the spin-orbit coupling in hybrid single-molecule magnet/non-magnetic metal thin film heterostructures to understand the impact of hybridization. For this, we inject a pure spin current at ferromagnetic resonance into the hybrid interface, allowing us to measure the spin-to-charge conversion efficiency. In this work, we utilize single-molecule magnets based on the metallacrown system, chosen for their unique combination of reliability and versatility. Quantifying the adsorption for molecular systems with different constitutions and planarity allows us to conclude the impact of molecular structure on the effective spin-orbit coupling and magnetic coupling at the hybrid interface, paving the path toward novel spintronic devices.

MA 46.76 Thu 15:00 Poster C

Computational Study of the Magnetic Properties of Simple Molecules Containing Boron-Boron Bonds — •Ljubica Dimova and Irina Petreska — Ss. Cyril and Methodius University in Skopje, Faculty of Natural Sciences and Mathematics, Institute of Physics, Skopje, Macedonia

Our results from the computational studies of the spin properties of some selected paramagnetic molecular species will be presented. Experimentally, the properties of the paramagnetic molecules are investigated by the electron paramagnetic resonance (EPR) spectroscopy, which is usually complemented by the density functional theory (DFT). DFT plays a significant role in prediction of the molecular magnetic properties, as well as in the rationalization of the experimentally observed EPR spectra. We start our DFT study with the diboron molecule, as a simple example, found in a triplet ground state, due to the two unpaired electrons. Further, we extend our analysis to more complex compounds, containing boron-boron bonds, aiming at investigation of the effects of the surrounding. In particular, we evaluate the **g**-tensor values, including the relativistic mass correction, diamagnetic correction, orbital Zeeman and spin-orbit coupling contributions. For this purpose, we employ the GIAO (Gauge-Independent Atomic Orbital) method to fully optimised structures at various levels of theory. The obtained results are analysed in detail and compared with the existing experimental data.

MA 46.77 Thu 15:00 Poster C

Laser-induced generation of magnetic fields on an ultrafast timescale — •Hannah Bendin, Benjamin Schwager, and Jamal Berakdar — Martin-Luther-Universität Halle-Wittenberg

Enabling ultrafast switching of magnetic moments on a nanoscopic scale is an important step on the path to minimization of electronic devices. Therefore, finding new ways of generating the respective magnetic fields is essential. In this project, the possibility of utilizing endohedral fullerenes for those purposes is investigated. Fullerenes possess superatom molecular orbitals (SAMOs). For the buckminsterfullerene, those diffuse excited states are similar in structure to hydrogen orbitals while being on a nanometer scale. Using an optical vortex beam to excite electrons and transfer spin as well as orbital angular momentum, charge currents can be generated in the SAMOs. The induced magnetic field inside the cage of the fullerene and the spin manipulation of enclosed atoms are investigated.

MA 46.78 Thu 15:00 Poster C

Magnetocalorics for spin systems with dipolar interaction — •Dennis Westerbeck and Jürgen Schnack — Bielefeld University

For the development of new coolants for the low temperature cooling, it is necessary to take a look at the influence of the inevitable dipolar interaction on the cooling efficiency. We investigated small spin systems with common shapes like rings, tetrahedrons and butterflys, to search for areas, where the dipolar interaction has the most favourable effect on important thermodynamic variables

MA 46.79 Thu 15:00 Poster C

Probing the magnetic behavior of the metastable high-spin state achieved by light-induced excited spin-state trapping in Fe (II) complexes — •Marcel Walter[1], Tarek Al Said[2], Clara W.A. Trommer[3], Torben Adam[3], Felix Tuczek[3], Karsten Holldack[2], Wolfgang Kuch[1], and Sangeeta Thakur[1] — [1]Freie Universität Berlin, Institut für Experimentalphysik, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [3]Institut für Anorganische Chemie, Christian-Albrechts Universität zu Kiel, 24098 Kiel, Germany

The magnetic behavior of the metastable high-spin (HS) state of the binuclear iron complex $[(Fe(H_2B(pz)_2)_2)_2$ (μ-bipy-ac-bipy)] and the mononuclear complex $[Fe(H_2B(pz)_2)_2(bipy)]$ was investigated at 5 K by electron paramagnetic resonance (EPR) spectroscopy in a magnetic field of 1-10 T. The relaxation time of the spins from the low-spin state to reach the metastable HS state after light-induced excited spin state trapping is faster for the binuclear complex (11 min) as compared to the mononuclear complex (16 min). The spin Hamiltonian parameters obtained from a simulation of the magnetic field map of the EPR measurements indicate a large value of zero-field splitting (ZFS) for both complexes, which can be explained by the contribution of spin-orbit coupling to the ZFS during the decay of the excited singlet states $^1T_{1g}$ to the excited $^5T_{2g}$ metastable HS state.

MA 46.80 Thu 15:00 Poster C

Submonolayer films of tridentate spin-crossover molecules with high transition temperatures deposited on graphite — •Jorge Torres[1], Sangeeta Thakur[1], Sascha Ossinger[2], Jan Grunwald[2], Ivar Kumberg[1], Evangelos Golias[3], Clara W.A. Trommer[2], Sebastien Hadjadj[1], Marcel Walter[1], Jendrik Gördes[1], Rahil Hosseinifar[1], Pin-Chi Liu[1], Tauqir Shinwari[1], Chen Luo[4], Lalminthang Kipgen[1], Florin Radu[4], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Freie Universität Berlin, Berlin, Germany — [2]Christian-Albrechts Universität zu Kiel, Kiel, Germany — [3]MAX IV Laboratory, Lund, Sweden — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Spin-crossover molecules (SCM) are organic metal complexes the spin states of which can be changed from low-spin (LS) to high-spin (HS) by stimulation with light, temperature or pressure. Here, we use x-ray absorption (XAS) and differential reflectance (DRS) spectroscopies to study bulk and submonolayer coverages of sublimable tridentate SCM's on graphite. Submonolayer films of $[Fe\{H_2B(pz)(pypz)\}_2]$, which can exist in two different polymorphic structural phases, exhibit a transition temperature ($T_{1/2}$) around 300 K. For the nominal LS complex $[Fe\{pypypyr\}_2]$ ($T_{1/2}$ above 510 K), XAS bulk measurements show a long-lived low-temperature HS state. Finally, $[Co\{H_2B(pz)(pypz)\}_2]$ and $[Co\{dpzca\}_2]$ show a reduced light-induced excited spin-state trapping (LIESST) efficiency compared to the thermally driven spin transition. From these results, a link between polymorphic phases and LIESST temperatures as a function of film thickness might exist.

MA 46.81 Thu 15:00 Poster C

Chiral Induced Spin Selectivity Effect at Helical Molecule-metal Interfaces — •Ashish Moharana[1], Hao Wu[2], Shuanglong Wang[2], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1], Zijie Qiu[2,3], Tomasz Marszalek[2], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Max Planck Institute for Polymer Research, Ackermannweg 10, 55128, Mainz, Germany — [3]School of Science and Engineering, Shenzhen Institute of Aggregate Science and Technology, The Chinese University of Hong Kong, Shenzhen, 518172, P.R. China

The observation of spin-dependent transmission of electrons through chiral molecules has led to the discovery of chiral-induced spin selectivity (CISS). The high efficiency of the spin filtering effect in chiral molecules has recently gained significant interest due to the high potential for novel hybrid molecule magnetic spintronics applications. However, the fundamental mechanisms underlying the CISS effect at the molecule-metal interface remain not entirely understood. In our work, we explore spintronic phenomena at hybrid chiral molecule magnetic interfaces to elucidate the underlying mechanisms of the chiral-induced spin selectivity effect. For this, we investigate the spin-to-charge conversion efficiency in chiral molecule/ metallic thin film heterostructures. This study focuses on the impact of the adsorption of chiral molecules on the spin-to-charge conversion at the molecule-metal hybrid interface. Quantifying the impact as a function of the molecular structure of the chiral molecules will reveal the role of the structural design in the spin-filtering effect.

MA 46.82 Thu 15:00 Poster C

Density-functional studies of $CuCu_4$ metallacrowns deposited on gold surfaces — •Ariyan Tavakoli, Benedikt Baumann, Stefan Lach, Benjamin Stadtmüller, Christiane Ziegler, and Hans Christian Schneider — Physics Department, RPTU Kaiserslautern-Landau, KaiserslauternGermany

We present ab-initio calculations for the electronic and magnetic properties of CuCu4 metallacrowns [1] adsorbed on an Au (111) surface for different deposition methods. In the framework of the VASP code, we compare gas-phase results obtained using DFT and DFT+U calculations, and investigate the DOS and ligand structure of the different hybridized systems.

[1] P. Happ et al., Phys. Rev. B 93, 174404 (2016).

MA 46.83 Thu 15:00 Poster C

Magnetic structure of $Cu(tn)Cl_2$ molecular magnet — •Jakub Šebesta[1], Dominik Legut[1], Robert Tarasenko[2], Olha Vinnik[2], Erik Čižmár[2], Jozef Strečka[2], Martin Orendáč[2], and Alžbeta Orendáčová[2] — [1]IT4Innovations, VŠB-TU Ostrava, 17.listopadu 2172/15, 708 00 Ostrava, Czech Republic — [2]Institute of Physics, P. J. Šafárik University, Park Angelinum 9, 04001 Košice, Slovakia

Magnetic materials have long been the subject of scientific inquiry. Nevertheless, the research started to expand its focus beyond aiming at low-dimensional systems. Exploring beyond the traditional bulk magnets could bring innovations thanks to different confinement resulting in unique physical properties. Apart from layer materials, molecular magnets are significant representatives. In this work, we are discussing an organo-metallic $Cu(tn)Cl_2$ quantum magnet bearing a 2D layered magnetic structure. Combining DFT calculations with an evaluation of magnetic exchange interactions, we discuss the magnetic complex structure and show the strong dependence of the magnetic properties on molecular conformation. It includes not only the variation of the magnetic exchange but also the modification of the magnetic state itself.

MA 46.84 Thu 15:00 Poster C

On the magnetocaloric effect of terbium in high fields — •Tino Gottschall[1], Michael Kuz'min[2], Eduard Bykov[1], Deborah Schlagel[3], Yaroslav Mudryk[3], and J. Wosnitza[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Aix-Marseille Université, France — [3]Ames Laboratory, U.S. Department of Energy, USA

Magnetic cooling is a refrigeration technique that is based on the so-called magnetocaloric effect, the change of temperature caused by a magnetic field. It can be utilized to construct environmentally friendly cooling devices, air conditioners, and heat pumps. The element gadolinium plays a special role in this context, as it has an extraordinary large magnetocaloric effect at room temperature. In this presentation, however, we would like to focus on another rare-earth element, namely terbium. We show on a single crystal that it even outperforms gadolinium in terms of the adiabatic temperature change in high pulsed magnetic fields. Due to the extremely strong magnetic anisotropy, we have also observed an enormous rotational magnetocaloric effect, which could be interesting for the development of future magnetic-cooling devices.

MA 46.85 Thu 15:00 Poster C

Estimation of the conventional giant barocaloric effect in $Ni_{50}Mn_{34.8}In_{14.2}B$ — •Sven Wiesekopsieker[1,2], Tapas Samanta[1], Chris Taake[1], Laila Bondzio[1], Andreas Hütten[1], and Luana Caron[1,2] — [1]Faculty of Physics, Bielefeld University, Bielefeld 33501, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin 12489, Germany

Heusler alloys such as NiMn(In, Ga, Sn)-based systems are of special interest because they display a magnetostructural transition of first-order, necessary for a large barocaloric effect (BCE)[1]. The off-stoichiometric Heusler alloy $Ni_{50}Mn_{34.8}In_{14.2}B$ shows a martensitic phase transition from a low T, low moment martensitic phase with monoclinic structure to a high T, ferromagnetic austenite phase with cubic L21 structure. We have studied the BCE in this compound using a combination of magnetic measurements under hydrostatic pressure and differential scanning calorimetry at 1 atm. Application of a pressure up to 8.2 kbar shifts the transition from 305 K up to 327 K and decreases thermal hysteresis from ca. 6.5 to 4.5 K at $\mu_0 H = 7$ T. This, combined with a large transition entropy change of $|\Delta S_{tr}| = 35$ J/(kg K), results in a decent refrigeration capacity which, compared to similar systems such as $Ni_{58.3}Mn_{17.1}Ga_{24.6}$ with $\Delta T_{hyst} = 11$ K and $|\Delta S_{tr}| = 16$ J/(kg K) [2], or $Ni_{44.6}Co_{5.5}Mn_{35.5}In_{14.4}$ with $\Delta T_{hyst} = 19$ K and $|\Delta S_{tr}| = 16$ J/(kg K) [1], represents a large improvement.

[1] X. J. He et al., J. Scri. Mater. 145, 58 (2018)
[2] X. J. He et al., J. Mater. Sci. 52, 2915 (2017)

MA 46.86 Thu 15:00 Poster C

Anomalous Nernst effect in Ge-substituted iron nitride thin films — •Jakub Vit[1], Petr Levinsky[1], Kyo-Hoon Ahn[1], Marketa Jarosova[1], Imants Dirba[2], and Karel Knizek[1] — [1]Institute of Physics, Czech Academy of Sciences, Prague, Czechia — [2]TU Darmstadt, Germany

Iron nitrides – composed of abundant elements – have Curie temperatures (T_C) well above the room temperature, below which they exhibit the anomalous Nernst effect (ANE) larger than pure iron. [1] Our recent DFT calculations suggested that the ANE may be further increased by substitution of other elements for iron. [2] Nevertheless, synthesis of such theoretically predicted compounds may be complicated. One of few successful syntheses of substituted iron nitrides is the case of $Fe_{4-x}Ge_xN$ (x=0 – 1) antiperovskites, which were characterized in a form of powder. [3] We investigated the same compounds grown as epitaxial thin films, which provides convenient geometry for thermoelectric applications. Upon Ge-doping, T_C expectedly decreases and the cubic structure becomes tetragonal. We measured magnetic properties, resistivity and the Nernst effect, the latter changing sign upon varying Ge content with comparable magnitude to Fe_4N. This was reproduced in our DFT calculations when selecting the on-site Coulomb repulsion parameter U=1 eV, showing that finite U is necessary to use despite broad bands, typical for nitrides.

[1] S. Isogami et al., *Appl. Phys. Express*, **10**, 073005 (2017)
[2] K.-H. Ahn et al., *Phys. Rev. B*, **108**, 075123 (2023)
[3] T. Scholz and R. Dronskowski, *J. Mater. Chem. C*, **5**, 166 (2017)

MA 47: Poster III

Time: Thursday 15:00–18:00 Location: Poster D

MA 47.1 Thu 15:00 Poster D

Twisted magnetocaloric effect by exchange bias in double perovskite SmCaCoMnO6 — •Manisha Bansal, Wasim Akram, and Tuhin Maity — School of Physics, Indian Institute of Science Education and Research Thiruvananthapuram, Thiruvananthapuram, Kerala 695551, India

Exchange bias (EB) is unarguably popular magnetic phenomenon due to its industry oriented applicability like memory devices and sensors. EB is widely reported in various types of materials such as core-shell nanoparticles, multiferroics, double-perovskites (DP), etc. Here, we report a twisted magneto caloric effect (MCE) from twisted crossover between isothermal magnetic hysteresis (MH) curves, due to a giant EB of ~8500 Oe in DP system of ferrimagnetic (FIM) SmCaCoMnO6-ferromagnetic (FM) Sm0.1Ca0.9MnO3 at T*10 K. The twisted MCE leads to an enhanced inverse MCE (entropy change ~ -3 J/Kg-K for the change of field ~70 kOe at 2 K); three times greater than the direct MCE observed. Both MCE and EB are found to be highly field dependent. Variation of EB with bias field emphasizes the importance of de-pinning threshold field which corroborates with the behavior of isothermal MH curves with respect to the field at low temperatures. The strong coupling between EB and MCE effects is due to the spin glass between the primary FIM SmCaCoMnO6 and secondary FM Sm0.1Ca0.9MnO3 phases, confirmed by magnetic remanence, ac susceptibility, and time dependent magnetic relaxation measurements. Thus, both EB and MCE have a common origin. The interesting results will lead to energy-efficient spintronic devices.

MA 47.2 Thu 15:00 Poster D

Out-of-plane magnetoresistance in vortex magnetic tunnel junctions — •Johannes Demir, Tobias Peters, Karsten Rott, and Günter Reiss — Bielefeld University, Germany

We investigated the magnetoresistance (MR) in magnetic tunnel junctions (MTJs) where the free layer magnetization exhibits a magnetic vortex state. The MTJ is a standard tunnel magnetoresistance (TMR) stack with a thin Ta layer and a thickness varied FeB layer as the vortex layer on top, nanostructed into pillars with different diameters. MR measurements are performed by bonding the MTJ pillars to the contact pads of a chip carrier and applying a bias voltage in the mV range. Sweeping the out-of-plane (OOP) magnetic field between 2 T and -2 T we observe a nearly parabolic behaviour for the current flowing through the pillar saturating in dependence of the diameter of the pillar and the thickness of the vortex layer. Here, MR ratios of up to 60 % were achieved. Micromagnetic simulations reveal a tilting of the magnetization towards the magnetic field direction for both the vortex and reference layer. The evaluation of the simulations with a cosine-model [1] leads to a good agreement with the measurements.

[1] A. Tavassolizadeh et al., Appl. Phys. Lett. **102**, 153104 (2013)

MA 47.3 Thu 15:00 Poster D

Magneto-Plasmonic Quasicrystal structure for Broadband Faraday Rotation Enhancement — •Shraddha Choudhary[1,2], Gajendra Mulay[1], and Venu Gopal Achanta[1] — [1]Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental Research, Mumbai 400005, India. — [2]Institute of Physics, University of Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany

Magneto-plasmonic nanostructures integrating plasmonics and magneto-optics offer a novel way of controlling light using magnetic fields. The Faraday effect in magneto-optical materials causes a rotation of the polarization plane of light, which is primarily utilized in non-reciprocal photonic devices such as optical isolators and circulators. However, existing magneto-optical materials exhibit a weak Faraday effect in the visible to the near-infrared frequency range, resulting in bulky Faraday isolators. In this study, we report a broadband enhancement in the Faraday rotation in a plasmonic quasicrystal (PlQC) structure comprising of patterned gold pillars on top of ferromagnetic thin films. The enhancement primarily results from the excitation of surface plasmon polaritons that propagate at the interface between gold and garnet in the PlQC structure.

MA 47.4 Thu 15:00 Poster D

Spin Noise Experiments in Yttrium Iron Garnet Films — •Franz S. Herbst, Daniel Anic, Marvin A. Weiss, and Sebastian T. B. Goennenwein — Department of Physics, University of Konstanz, Germany

Thermal spin fluctuations can be used as a powerful yet non-perturbative experimental probe for the magnetic behavior of correlated materials. The analysis of magnetization fluctuation data using different statistical metrics, such as autocorrelation or noise power spectral density, grants direct access to equilibrium material properties and incoherent magnetization dynamics - even down to ultrafast time scales [1].

Yttrium Iron garnet ($Y_3Fe_5O_{12}$, YIG) is considered as a prototypical material for future spintronic devices, due to its extremely low magnon damping. However, spin fluctuations in YIG have not been systematically studied to date. Here we investigate the magnetization noise in YIG over a broad range of frequencies and for different external magnetic fields using the magneto-optical Faraday effect. We analyze our experimental data in particular regarding non-stationary relaxation processes and assess the effect of non-ergodicity using toy model simulations.

[1] Weiss et. al., Nat. Commun. **14**, 7651 (2023).

MA 47.5 Thu 15:00 Poster D

Crystallization behavior of Yttrium Iron Garnet thin films — •Sebastian Sailler[1], Gregor Skobjin[1], Benny Boehm[4,5], Heike Schlörb[2], Olav Hellwig[4,5], Andy Thomas[2,3], Sebastian T.B. Goennenwein[1], and Michaela Lammel[1] — [1]Department of Physics, University of Konstanz, Konstanz — [2]Leibniz Institute of Solid State and Materials Science, Dresden — [3]TUD Dresden University of Technology, Dresden — [4]Institute of Physics, Technische Universität Chemnitz, Chemnitz — [5]Center for Materials Architectures and Integration of Nanomembranes (MAIN), TU Chemnitz, Chemnitz

Yttrium iron garnet (YIG) is a ferrimagnetic insulator commonly used in spin transport and spin dynamics. High quality, single crystalline YIG thin films are typically fabricated, e.g., using sputter deposition at room temperature with a subsequent annealing step to induce crystallization. Interestingly, however, the exact crystallization dynamics from the amorphous to the crystalline state have not been systematically studied. We therefore analyze the crystallization behavior of YIG films on different substrates utilizing extensive annealing temperature and time series. Structural characterization using X-ray techniques as well as electron backscatter diffraction allow to differentiate between amorphous, partially crystalline, polycrystalline and epitaxial films, and to determine the optimal annealing parameters for each substrate. Our results provide an in-depth understanding about the formation of crystalline YIG and allow for a rigorous control over the crystallization induced by the subsequent annealing step.

MA 47.6 Thu 15:00 Poster D

Lateral Solid Phase Epitaxy of Yttrium Iron Garnet — Sebastian Sailler[1], Darius Pohl[2], Heike Schlörb[3], Bernd Rellinghaus[2], Andy Thomas[3,4], Sebastian T.B. Goennenwein[1], and •Michaela Lammel[1] — [1]Department of Physics, University of Konstanz, Konstanz — [2]DCN, cfaed, TUD Dresden University of Technology, Dresden — [3]Leibniz Institute of Solid State and Materials Science, Dresden — [4]TUD Dresden University of Technology, Dresden

Lateral solid phase epitaxy of yttrium iron garnet (YIG) enables the fabrication of single crystalline YIG on top of non-lattice matched carrier materials and therefore the realization of single crystalline, non-planar YIG structures. We demonstrate the lateral solid phase epitaxy of YIG over an artificial edge, such that the crystallization direction is perpendicular to the initial seed. We use micropatterned SiO_x mesas on top of single crystalline garnet seed substrates to study the lateral crystallization across and on top of the SiO_x. We find that YIG retains the crystal orientation of the substrate not only when in direct contact with the seed garnet, but also across the edge on top of the SiO_x mesa. By controlling the crystallization parameters it is possible to almost completely suppress the formation of polycrystals and to enable epitaxial growth of single crystalline YIG on top of SiO_x. From a series of annealing experiments, we extract an activation energy of 2.8 eV and a velocity prefactor of 5.1×10^{13} nm/s for the lateral crystallization of YIG along the <100> direction. Our results pave the way to engineer single crystalline non-planar yttrium iron garnet structures with controlled crystal orientation.

MA 47.7 Thu 15:00 Poster D

Giant current driven magnetic response in Ca_2RuO_4 — •Aditya Putatunda, Ravi Kaushik, and Sergey Artyukhin — Istituto Italiano di Tecnologia, Genova, Italy 16163

Current driven manipulation of spin states in magnetic systems, mediated via spin-orbit torque has attracted significant attention in recent times due to its performance potential for high speed, low power switching in the form of novel devices1. The ability to realize this functionality in antiferromagnetic systems offer the extra advantage of insensitivity to magnetic field perturbations, while being readily compatible with metal, semiconductor, or materials with an insulating electronic structure2.

Here we report our theoretical investigation on Ca2RuO4, an antiferromagnetic insulator, driven by strong $4d$ spin-orbit interactions, exploring the recently observed Raman spectra measurements. Driven by a miniscule current, prior to the onset of its conductivity transition, this material shows significant alteration to its low energy spectra, apparently due to a spin-flop transition. We will be discussing our analytical model, supported by first-principles calculations offering an explanation to this novel observation3.

1 Soumyanarayanan et al., Nature 539, 509517 (2016) 2 Železný et al., Phys. Rev. Lett. 113, 157201 (2014) 3 Kunkemöller et al., Phys. Rev. B 95, 214408 (2017)

MA 47.8 Thu 15:00 Poster D

Catalogue of C-paired spin-valley locking in antiferromagnetic system — •Mengli Hu[1], Xingkai Cheng[2], Zhenqiao Huang[2], and Junwei Liu[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Department of Physics, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China

We propose an algorithm to determine C-paired spin-valley locking (SVL) in any magnetic space group (MSG) based on the little co-group and coset representatives, which allows us to naturally classify C-paired SVL into collinear, coplanar, and spatial categories and identify four elementary types that compose all possible C-paired SVL in 1651 MSGs. By combining the proposed algorithm and high-throughput first-principles calculations, we identify 140 out of 1794 antiferromagnetic (AFM) materials from MAGNDATA that can realize C-paired SVL with experimentally verified magnetic structure. Besides identifying new material candidates, the classification can also reveal the underlying mechanism of responses of C-paired SVL to external fields. As an example of $PbNiO_3$, two qualitatively different types of piezomagnetism via occupation imbalance or spin tilting can be realized by breaking the little co-group or coset representatives, respectively. Moreover, our algorithm is also applicable to locking between valley/momentum and any kind of pseudo-vector degree of freedom, e.g. Berry curvature distribution, as demonstrated in the example of $PbNiO_3$.

MA 47.9 Thu 15:00 Poster D

Strain Tuning of the Altermagnetic Candidate MnF_2 — •Rahel Ohlendorf[1,2], Hilary M. L. Noad[1], Elena Hassinger[2], Andrew P. Mackenzie[1,3], and Elena Gati[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [2]Technical University, Dresden, Germany — [3]University of St Andrews, UK

Altermagnetism is a newly defined collinear magnetic phase unambiguously differentiated from the already known ferro- and antiferromagnetic phases within the framework of spin group symmetry [1]. This magnetic phase combines the highly sought after properties of compensated spin order in real space and spin-split bands in reciprocal space even without spin-orbit coupling, relevant for spintronic applications. Similar to the magnetic field for ferromagnets, the combination of strain and magnetic field is predicted to act as a conjugate field to the altermagnetic order parameter. Consequently, strain and magnetic field might be used to (i) probe the altermagnetic susceptibility, related to octupolar degrees of freedom in centrosymmetric systems and (ii) create a single-domain altermagnetic state exploiting the piezomagnetic effect [2,3]. We discuss the results of elastocaloric and stress-strain measurements of the altermagnetic centrosymmetric candidate MnF_2 under finite strain and magnetic field.

[1]L. Smejkal et al., Phys. Rev. X 12, 031042 (2022)
[2]S. Bhowal et al., ArXiv: 2212.03756v1 (2022)
[3]L. Ye et al., ArXiv: 2309.04633v1 (2023)
*Work is supported by the DFG through TRR288 (Elasto-Q-Mat).

MA 47.10 Thu 15:00 Poster D

Growth and surface characterization of epitaxial $CuFeS_2$ thin films on Si(001) — •Richard Justin Schenk, Anders Christian Mathisen, Stefanie Suzanne Brinkman, Xin Liang Tan, Matthias Hartl, Christoph Brüne, and Hendrik Bentmann — Center for Quantum Spintronics, Department of Physics, NTNU, Trondheim, Norway

Chalopyrite, $CuFeS_2$, has recently gained attention as a semiconducting, collinear antiferromagnet with a high Néel temperature (T_N = 823 K). As a representative of the magnetic space group ($I\bar{4}2d$) it has been predicted to host non-relativistic spin-polarized electronic bands, which have generated great interest in recent years in the context of altermagnetism. These properties make chalcopyrite a suitable candidate for future spintronics applications. We present $CuFeS_2$ thin films on a lattice-matched Si(001) substrate using molecular beam epitaxy. We will report on surface preparation and characterization of the films based on low-energy electron diffraction (LEED) and X-ray photoelectron spectroscopy (XPS). Furthermore, the electronic structure of these films was investigated by laboratory-based photoelectron momentum microscopy and soft X-ray angle-resolved photoemission spectroscopy (ARPES).

MA 47.11 Thu 15:00 Poster D

Ab-inito prediction of chiral spin structures in antiferromagnetic MnN based thin films — •Victor Deinhart[1,2,3], Stefan Blügel[2], and Felix Büttner[1,3] — [1]Helmholtz-Zentrum Berlin, 14109 Berlin, Germany — [2]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Universität Augsburg, 86159 Augsburg, Germany

Chiral magnetic structures are non-trivial spin structures with a topological charge and can exist in host materials with perpendicular magnetic anisotropy (PMA) where stray fields and Dzyaloshinskii-Moriya interaction (DMI) stabilize them. While chiral structures are readily observed in ferromagnetic materials, their existence in natural antiferromagnets (AFM) has still to be shown. To identify material systems able to host chiral spin structures, we study AFM/heavy metal heterostructures with the aim to stabilize these via spin-orbit interaction induced DMI. Herein, we focus on systems based on θ-MnN, the nitrogen richest phase of all MnN based compounds, featuring an antiferromagnetic ordering and PMA [1]. We present ab-initio calculations of the magnetic exchange interactions based on the FLEUR density functional theory code. Via subsequent atomistic spin simulations, the stability and properties of possible chiral spin structures in the considered thin film systems are analyzed and the most promising material systems for future experimental realization are discussed.

[1] Zilske et al., Appl. Phys. Lett. 110, 192402 (2017)

MA 47.12 Thu 15:00 Poster D

Detection of Nanoscale Magnetic Fields with Scanning NV Magnetometry — •Ricarda Reuter, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

The key component of Scanning nitrogen-vacancy (NV) measurements is the NV center, a point defect in a diamond host lattice. Due to its unique electronic structure, the NV center can be utilized to detect magnetic fields with sensitivities up to several nT/sqrt(Hz), which are read out optically. Scanning NV setups combine an optical excitation/detection path with an Atomic Force Microscope (AFM), ideally providing nanoscale magnetic and spatial resolution at the same time.

However, the actual magnetic resolution of Scanning NV depends on several factors, including the distance between NV center and sample surface, the shape of the nanodiamond tip, and the measurement time. Quantities like the coherence time and optically detected magnetic resonance (ODMR) contrast of the NV center have to be considered as well.

We discuss the impact of these factors on measurements of typical nanoscale magnetic structures with different characteristic dimensions and compare our results to vacuum Magnetic Force Microscope (MFM) measurements. Due to the versatility of our approach, the sensitivity of other magnetic field sensors such as Hall or SQUID sensors can be calculated in a similar way by considering the respective sensor's parameters. This way, assessing the magnetic resolution and comparing different measurement techniques will be simplified significantly.

MA 47.13 Thu 15:00 Poster D

MAXPEEM: Unique magnetic imaging at MAX IV laboratory — •Evangelos Golias, Yuran Niu, and Alexei Zakharov — MAX IV Laboratory, Lund University, Box 118, 22100 Lund, Sweden

The MAXPEEM beamline at the MAXIV synchrotron facility in Lund, Sweden, houses a state-of-the-art aberration-corrected spectroscopic photoemission and low-energy electron microscope (AC-SPELEEM). MAXPEEM is ideal for studies in material and surface science, 2D and low-dimensional systems, industrial applications, and magnetism. MAXPEEM can perform electron or photoelectron microscopy, diffraction and spectroscopy with spatial resolution down to a single digit in nm. MAXPEEM is the only beamline in the world where x-rays impinge perpendicular to the sample, a geometry that is beneficial for studying particular ferromagnetic and antiferromagnetic systems using x-ray magnetic circular (linear) dichroism (XMCD-PEEM, XMLD-PEEM). Here we present the technical capabilities of the MAXPEEM end-station along with sample studies that highlight how MAXPEEM can accelerate users' magnetic material research.

MA 47.14 Thu 15:00 Poster D

Quantitative magneto optical stray field characterization for magnetic scales — •Nils Magin and Sibylle Sievers — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We present the application of magneto optical indicator film based magnetic field measurements to the characterization of magnetic scales. Magnetic scales with incremental pole pattern are combined with Hall or magneto-resistive sensors to build robust magnetic encoders. However, quality control of these scales requires a spatially resolved quantitative analysis of their stray field distribution, which is not possible with the typically several 100 μm wide encoder sensors.

MOIF is a fast (sub second resolution) imaging technique that allows a one-shot characterization and thus high throughput of samples with areas of several square centimeters. It combines the capability to detect fields from the millitesla (mT) to the tesla (T) range with sub-micron spatial resolution. Additionally, it can be used for rough samples without the need for surface treatments.

We here apply magneto-optical indicator film measurements to the characterization of the stray field distribution of magnetic scales and propose procedures to derive parameters of magnetic scales like pole width and field amplitude. The calibration and uncertainty of MOIF based characterizations is discussed.

This project (EMPIR 20SIP04 qMOIF) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

MA 47.15 Thu 15:00 Poster D

Quantitative evaluation of disordered remagnetization processes by Kerr microscopy — •Xian Yue Ai[1], Ivan Soldatov[2], Leon Oleschko[1], Rudolf Schäfer[2], and Sebastian T.B. Goennenwein[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Institute for Emerging Electronic Technologies, IFW Dresden, Germany

A quantitative understanding of magnetic domain wall (DW) nucleation and propagation is important not only from a scientific perspective, but also for applications, e.g., in magnetic data storage devices. To date, DW velocity experiments often focus on one single propagation direction, and rely on magnetic field pulses to induce a step-wise DW motion. Strongly disordered, statistic magnetization dynamics remains a topic addressed mostly via simulations and theory.In our study, we use series of Kerr microscopy images taken as a function of time at constant magnetic field to explore re-magnetization in Pt/Co/AlO_x thin films with perpendicular magnetic anisotropy. Inevitable mechanical vibrations and camera noise impede a direct spatially resolved analysis of re-magnetization in the creeping regime. To mitigate these issues, we have developed an approach based on analytical image processing techniques in combination with a correlation-based computational scheme. Our analysis scheme thus enables a quantitative categorization of highly disordered magnetization dynamics with unprecedented resolution. Our technique can be straightforwardly implemented in modern Kerr microscopes, opening interesting perspectives for magnetic material analysis.

MA 47.16 Thu 15:00 Poster D

Advanced transmission electron microscopy of the three-dimensional magnetization distribution of a pinned domain wall in a Sm-Co-based permanent magnet — Aurys Šilinga[1], Trevor P Almeida[1], •András Kovács[2], Ziyuan Rao[3], Tatiana Smoliarova[4], Konstantin P Skokov[5], Baptiste Gault[3], Oliver Gutfleisch[5], Michael Farle[4], and Rafal E Dunin-Borkowski[2] — [1]School of Physics and Astronomy, University of Glasgow, United Kingdom — [2]Ernst Ruska-Centre, Forschungszentrum Jülich, Germany — [3]Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany — [4]Faculty of Physics and Center for Nanointegration, Universität Duisburg-Essen, Duisburg, Germany — [5]Institute of Materials Science, Technische Universität Darmstadt, Darmstadt, Germany

Sm(CoFeCuZr)7 permanent magnets have a high energy product and are commonly used in applications at elevated temperature. Their high coercivity results in part from the pinning of magnetic domain walls at Sm2Co17 and SmCo5 phase boundaries. Here, we use the advanced transmission electron microscopy technique of electron holographic tomography, in combination with model-based reconstruction, to measure the three-dimensional magnetization distribution at a pinned domain wall in a needle-shaped sample of the permanent magnet Sm(CoFeCuZr)7 . The results are discussed by considering both the shape and the magnetocrystalline anisotropy of the sample, as well local variations of its microstructure and chemical composition.

Financially supported by CRC/TRR 270 (HoMMage), Project-No. 405553726-TRR 270.

MA 47.17 Thu 15:00 Poster D

Visualizing Ferrimagnetic Domain Structure with Vector Maps in Dysprosium Iron Garnet — •Khang-Vi Becker[1], Julian Skolaut[2], Miela Josephine Gross[3], Caroline Ross[4], and Angela Wittmann[5] — [1]JGU, Mainz, Deutschland — [2]JGU, Mainz, Deutschland — [3]MIT, Cambridge, US — [4]MIT, Cambridge, US — [5]JGU, Mainz, Deutschland

Ferrimagnets play a key role in revolutionizing spintronic devices due to their favorable properties including low saturation magnetization and ultrafast spin dynamics. An in-depth understanding of the underlying mechanisms is paramount for the integration of ferrimagnets in next-generation memory technologies. For this, imaging the magnetic domain structure is a powerful tool. One method of visualizing magnetic textures are vector maps providing the opportunity to analyze the evolution of the orientation of the Néel vector. This poster will give detailed insight into constructing vector maps from x-ray magnetic linear dichroism images revealing the magnetic domain structure in Dysprosium Iron Garnet (DyIG) thin films. As this approach is based on an angle-dependent examination of the alignment of the Néel vector, this technique offers the possibility of expanding it to antiferromagnets.

MA 47.18 Thu 15:00 Poster D

Simultaneous Magneto-Optical Imaging of Temperature and Magnetic Fields Utilizing YIG Hysteresis Loops — •Michael Path and Jeffrey McCord — Institute for Materials Science, Kiel University, Germany

We present a novel approach for the simultaneous measurement of temperature and magnetic fields. By exploiting the Faraday effect in bismuth-doped yttrium iron garnet, changes in the magnetization state are detected through the rotation of the polarization axis. A Stokes polarization camera in a magneto-topical microscope is used for direct quantification of this rotation. The garnet is modulated with an external field to continuously measure four distinct points on the hysteresis loop. This enables a measurement of the saturation magnetization for temperature, as well as susceptibility and offset, allowing for a self-calibrated measurement of the out-of-plane component of the magnetic field. This method achieves a temporal resolution in the order of milliseconds and a spatial resolution in the micrometer range for temperature and magnetic field. To validate our method, we provide an example with a current-carrying wire.

MA 47.19 Thu 15:00 Poster D

Switching of Magnetic Force Microscopy probes in homogeneous and non-homogeneous magnetic fields — •Rachappa Ravishankar[1,2], Aniruddha Sathyadharma Prasad[1], Michael Heigl[3], Rudolf Schäfer[1], Yana Vaynzof[1,2], Manfred Albrecht[3], Thomas Mühl[1], and Volker Neu[1] — [1]Leibniz Institute for Solid State and Materials Research, 01069 Dresden — [2]Dresden University of Technology, 01187 Dresden — [3]University of Augsburg, 86159 Augsburg

In magnetic force microscopy's lift mode, long-range magnetic and electrostatic interactions dominate, and electrostatic contributions must be separated. This issue is resolved by switching magnetization MFM (SM-MFM), involving tip magnetization reversals between images allowing us to differentiate non-magnetic and pure magnetic forces by combining scanned data with original and reversed tip magnetization.

We investigate the switching of commercial MFM tips in both homogeneous and non-homogeneous fields. The homogeneous field in z-direction is provided by an electromagnet on which a high-coercive, ferrimagnetic TbFe is placed as a test sample. The non-homogeneous field is created by applying a current pulse into a micro coil patterned on a flat substrate. The magnetization states of the tip are probed on the TbFe sample and we observed a reverse, and low moment (partially magnetized) state. Finally, we characterize the tip magnetization by quantitative magnetic force microscopy (q-MFM) on a well-characterized Co/Pt sample in both reversed and partially magnetized states, determining the corresponding tip transfer function (TTF).

MA 47.20 Thu 15:00 Poster D

The importance of the angle of incidence in magneto-optical Kerr microscopy investigated at micron-sized pyramidical magnetic thin films — •Bhavadip Rakholiya, Christian Janzen, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

This study investigates the impact of shape anisotropy on the magnetic properties of micron-sized pyramidal magnetic thin films. Utilizing Magneto-Optical Kerr Microscopy (MOKE), we analyze shape-induced modifications in magnetic characteristics. MOKE, based on detecting changes in polarized light reflected from the sample, enables high-resolution examination of magnetic domains and their responses to external stimuli. Specifically, we focus on applying MOKE to study micron-sized pyramidal magnetic thin films, considering challenges related to optical interaction in non-uniform geometries. The spatially dependent angle of incidence introduced by pyramidal structures influences the magneto-optical response. Our findings underscore the significant influence of material shape on magnetic properties and stress the importance of considering light angle changes in MOKE studies of complex shapes, contributing to a deeper understanding of the interplay between shape, optics, and magnetism for enhanced control and application of magnetic materials in various technologies.

MA 47.21 Thu 15:00 Poster D

Understanding the role of phonons in the ion induced phase transition of FeV — •Simon Rauls[1], Benedikt Eggert[1], Shadab Anwar[2], Tom Helbig[1], Kay Potzger[2], Jürgen Lindner[2], Jürgen Fassbender[2], Rantej Bali[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Depending on the Fe concentration, the binary alloy $Fe_{1-x}V_x$ is usually *bcc*-ordered and exhibits a low energy product as well as low intrinsic Gilbert damping, which makes it a candidate platform for low-loss spintronic devices. While an optimum V concentration of $x = 0.2$ was found for the intrinsic Gilbert damping, at higher concentrations of $x = 0.4$ the formation of a paramagnetic (PM), amorphous phase can be exploited. Using post-growth ion irradiation on the 40 nm thin-films, a phase transition from PM to FM can be achieved, enabling one-step writing of FM structures in a PM template, yielding a Gilbert damping parameter of 0.0027. In order to gain a deeper understanding of the aforementioned phase transition, Nuclear Inelastic Scattering experiments were performed, giving direct insights into the Fe-partial vibrational density of states of the as-grown and ion irradiated films. Along with Mössbauer spectroscopy, the interplay of chemical and structural disorder is deduced.

We acknowledge funding by the DFG through project no. 322462997 and the ESRF for granting the beamtime at beamline ID18.

MA 47.22 Thu 15:00 Poster D

Magneto-transport studies on altermagnetic CrSb — •S. Naduvile Thadathil[1,2], M. Uhlarz[1], M. C. Rahn[2], T. Speliotis[3], J. Wosnitza[1,2], and T. Helm[1] — [1]Dresden High Magnetic Field Laboratory, HZDR — [2]Institute of Solid State and Materials Physics, TU Dresden — [3]Institute of Nanoscience and Nanotechnology, Demokritos, Greece

The recent discovery of a distinct magnetic phase called "altermagnetism" (AM) has been based on spin-symmetry groups. An anomalous Hall effect (AHE), as found in ferromagnets, has been predicted and observed in ruthenium dioxide (RuO_2) despite the antiparallel magnetic order, which is linked to the AM. Here, we present results from magnetotransport studies on micron-sized structures cut from single crystals of CrSb. The magnetoresistance and the Hall effect were investigated between 1.8 and 300 K in fields up to 16 T for structures with current applied along the *a* and *c* axis. Below 3 K and at low magnetic fields, the longitudinal resistance for structures where the current is applied along the *c* axis exhibits a significant deviation from the field-dependent high-temperature quadratic behavior. We observed a significant AHE in CrSb. Interestingly, a planar Hall contribution is observed when the current is applied along the *c* axis of the crystal, which is absent for the current applied along the *a* axis. These findings may provide further evidence for the altermagnetic phase.

MA 47.23 Thu 15:00 Poster D

Vortex-based magnetic field sensors characterised by in-plane and out-of-plane magnetic fields — •Sophie Knewitz[1], Giovanni Masciocchi[1,2], Johannes Paul[2], Mathias Kläui[1], and Angela Wittmann[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Sensitec GmbH, Mainz, Germany

Magnetic sensors are indispensable for several everyday applications, due to their ability to measure speed, position, and orientation by means of magnetic fields [1]. Vortex-based magnetic field sensors can exhibit higher performance compared to conventional magnetic sensors due to hysteresis-free behaviour and low noise levels [2]. For developing them, it is essential to know about the spin structures' behaviour.

This project investigates the in-plane (IP) and out-of-plane (OOP) field sensitivity of circular vortex-based sensors. Using tunnel magnetoresistance, hysteresis curves of the samples are measured with a 2D vector magnet for varying OOP magnetic fields. We find that the magnetic vortex devices are remarkably robust against OOP fields up to at least 175 mT. Additionally, the hysteresis curves are sensitive to small misalignment of the sample with respect to the field axis. This implies careful characterisation is paramount for ensuring comparability.

These features, robustness in OOP fields and sensitivity to angular displacement, are very advantageous for IP sensors by facilitating accurate measurements of IP fields and detecting angular deviations.

References

[1] Jogschies, et al. Sensors 15.11, 28665-28689 (2015).
[2] Suess, et al. Nature Electronics 1.6, 362-370 (2018).

MA 47.24 Thu 15:00 Poster D

Optimizing MPMS Measurement Precision through 3D Printed Sample Holders: A Systematic Study on $Ba_3CrN_3H_x$ — •Rebecca Müller-Zurlinden[1], Anton Jesche[1], Peter Höhn[2], Natalia Gloriozova[2], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

The accuracy of MPMS measurements depends on several critical factors, including sample geometry, mounting position and magnitude of the magnetic moment. In order to obtain the best possible results, these factors, as well as the background contribution of the sample holder have to be considered. This study investigates the advantages of using 3D printed sample holders in the context of determining the magnetic properties of $Ba_3CrN_3H_x$. Key benefits of 3D printed samples include uniform material in the holder throughout the MPMS scan range. A precisely designed sample space, printed to the exact dimensions of the sample minimises the measured background as well as axial or radial displacement errors during measurement. The sample space allows for mounting and measurement in any orientation, and measurement of reactive materials without contamination of varnish or adhesives. The airtight sample space ensures precise sealing allowing controlled mounting and measurement of air-sensitive samples. These benefits are demonstrated by precisely studying the field- and temperature-dependent magnetization of $Ba_3CrN_3H_x$ (x = 0 - 0.5).

MA 47.25 Thu 15:00 Poster D

Quantitative Magnetic Force Microscopy from nm to mm — •Christopher Habenschaden[1], Sibylle Sievers[1], Andrea Cerreta[2], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Park Systems Europe GmbH, Mannheim, Germany

Magnetic Force Microscopy (MFM) is a well-established technique in Scanning Probe Microscopy (SPM) allowing imaging of magnetic samples with spatial resolution of tens of nm and stray fields down to the mT range.

Spatial resolution and field sensitivity can be pushed to several nm and the hundred μT range by measuring in vacuum conditions due to a higher Q-factor of the cantilever oscillation. This increasing field sensitivity, in turn, also allows increasing the working distance from the surface. We show that for μm-patterned magnetic samples, signals well above the noise floor are detectable even up to 100 μm above the surface. This enables scanning of mm-sized structures, which can be realized either by stitching 100 μm MFM scans or by much less time-consuming stage-scanning.

We present an implementation of both techniques into a Park Systems NX-Hivac vacuum SPM. A phase-locked loop-based signal detection is used to ensure high sensitivity and elimination of non-linearities. This setup enables MFM measurements to cover the full length range from the nm-regime up to several millimeters and thus to bridge the gap in spatially resolved magnetic field measurements from nano scale SPM to macroscopic measurements using optical indicator films.

MA 47.26 Thu 15:00 Poster D

SquidLab - a user-friendly program for background subtraction and fitting of magnetization data — •Matthew Coak[1,2,3,4,5], Cheng Liu[3,6], David Jarvis[3], Seunghyun Park[4,5], Matthew Cliffe[7], and Paul Goddard[2] — [1]University of Birmingham, Birmingham, UK — [2]University of Warwick, Coventry, UK — [3]University of Cambridge, Cambridge, UK — [4]CCES Institute for Basic Science, Seoul, South Korea — [5]Seoul National University, Seoul, South Korea — [6]CamCool Research Ltd, Cambridge, UK — [7]University of Nottingham, Nottingham, UK

We present an open-source program with full user-friendly graphical interface for performing flexible and robust background subtraction and dipole fitting on magnetization data. For magnetic samples with small moment sizes or sample environments with large or asymmetric magnetic backgrounds, it can become necessary to separate background and sample contributions to each measured raw voltage measurement before fitting the dipole signal to extract magnetic moments.

Originally designed for use with pressure cells on an MPMS3 magnetometer, SquidLab is a modular object-oriented platform implemented in Matlab with a range of importers for different widely-available magnetometer systems and has been tested with a broad variety of background and signal types. The software allows background subtraction of baseline signals, signal preprocessing, and performing fits to dipole data. A plugin system allows users to easily extend the built-in functionality. Squidlab now has over 1000 downloads, to labs worldwide. (Coak et al Rev. Sci. Instr. 91, 023901 (2020)

MA 47.27 Thu 15:00 Poster D

Magnetic properties of FeNi thin film systems — •Inga Ennen, Roland Schubert, Nancy Töws, Laila Bondzio, and Andreas Hütten — Bielefeld University, Bielefeld, Germany

FeNi alloys are the basis for a large number of different technical materials. Despite their widespread use, e.g. in stainless steel or Hall sensors, the influence of magnetism on the martensitic phase transition in FeNi alloys is not fully understood.

In this contribution, we focus on the magnetic properties of FeNi thin film systems that exhibit high strain coupling due to the preparation of alternating layers crystallized mainly in the martensite and austenite phase. Magnetometry measurements as well as magnetic imaging techniques using a transmission electron microscope are applied to the thin film systems and correlated with micromagnetic simulations.

MA 47.28 Thu 15:00 Poster D

Real-time in-situ giant magnetoresistance measurements in Co/Cu multilayers during sputter deposition — •Michael Mattern, Jan Michael Schmalhorst, and Günter Reiss — Bielefeld University, Faculty of Physics, Germany

Magnetoresistive sensors generate important input information that is further processed in complex microelectronic systems in a wide range of applications. For optimization purposes or the investigation of new material combinations, a permanent analysis of the influence of deposition conditions on the magnetoresistive performance is necessary. Today, research and development in the field of magnetic sensor technology ist slowed down due to slow feedback from results of ex-situ characterization of samples into modelling and production. This study presents an experimental technique for real-time in-situ measurements of magnetoresistive effects, such as giant magnetoresistance (GMR), during the sputtering process. As an example, an oscillating in-plane magnetic field with an amplitude of 420 Oe and a frequency of 10 Hz was applied to samples of cobalt/copper multilayers during film growth. By employing advanced instrumentation with a sampling rate of 20 kS/s and the implementation of real-time GMR amplitude calculation, we were able to obtain and analyze complete R versus H curves within 100 milliseconds. Correlations between the magnetic response of these samples and structural changes at different stages of film deposition are shown.

MA 47.29 Thu 15:00 Poster D

Ferromagnetic quantum critical point in $Sr_{1-x}Ca_xRuO_3$ approximated by artificial $[SRO_n/CRO_m]_l$ superlattices — •Robin Heumann, Robert Gruhl, and Philipp Gegenwart — Experimentalphysik VI, Universität Augsburg, 86159 Augsburg, Germany

Partial substitution of smaller Ca to the Sr site in the itinerant ferromagnetic $SrRuO_3$ (SRO) leads to the suppression of magnetic order and interesting non-Fermi liquid properties beyond about 70% Ca concentration [1]. However, the quantum critical point can smear out strongly by structural disorder [2]. Therefore, we explore the possibility whether a quantum critical point could also be realized in structurally ordered epitaxial heterostructures of SRO and $CaRuO_3$ (CRO).

Heterostructures $[SRO_n/CRO_m]_l$/STO(001) with $m = 2n$ and $m = 3n$ were prepared by metal organic aerosol deposition. Structural studies were performed via X-ray diffraction, reciprocal space mapping and TEM imaging. The electronic and magnetic properties were investigated via Hall-, magnetoresistance and magnetization measurements and compared to $Sr_{1-x}Ca_xRuO_3$ thin films with $x = 2/3$ and $x = 3/4$.

[1] M. Schneider *et al.*, phys. stat. sol. (b), **247** (2010) 200983004.
[2] L. Demkó *et al.*, Phys. Rev. Lett **108** (2012) 185701.

MA 47.30 Thu 15:00 Poster D

Isotropic Exchange-Bias in Twinned Epitaxial Co/Co3O4 Bilayer — •Martin Wortmann[1], Tapas Samanta[1], Maik Gaerner[1], Michael Westphal[1], Johannes Fiedler[2], Inga Ennen[1], Andreas Hütten[1], Tomasz Blachowicz[3], Luana Caron[1,4], and Andrea Ehrmann[2] — [1]Bielefeld University, Bielefeld, Germany — [2]Bielefeld University of Applied Sciences, Bielefeld, Germany — [3]Silesian University of Technology, Gliwice, Poland — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Exchange bias (EB) is a unidirectional anisotropy caused by interface coupling between a ferro- and an antiferromagnet. It causes a preferential direction of magnetization in the ferromagnet, which manifests as a shift of the hysteresis loop along the magnetic field axis. Here, we demonstrate a large EB of over 1000 Oe at 20 K in a twinned Co(111)/Co3O4(111) thin film epitaxially grown on sapphire(0001) with 6-fold rotational lattice symmetry, which is among the highest values reported for Co/Co1-yO systems. In such systems, the effect intensity is largest along the magnetic easy axes, which usually results in an anisotropy of the EB in epitaxial interfaces. However, we observed identical EB values for 0°, 15°, and 30° angles between the magnetic field and the nearest Co[002] magnetic easy axes. The measurements imply a relaxation of the magnetization to the nearest easy axis, suggesting increasingly isotropic EB fields with higher orders of rotational lattice symmetry.

MA 47.31 Thu 15:00 Poster D

Magneto-optical investigation of epitaxially grown Mn_2Au on Au capped Nb(100) — •Jendrik Gördes[1], Tauqir Shinwari[1], Tingwei Li[1], Arne Vereijken[2], Christian Janzen[2], Arno Ehresmann[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Berlin, Germany — [2]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

Antiferromagnetic materials are promising candidates for future data storage devices due to the absence of magnetic stray fields and spin dynamics in the THz range. Mn_2Au stands out as a particularly promising material, capable of electrical switching [1] through Néel spin-orbit torque without the need for an additional heavy metal layer. Here, we report on the co-evaporation of Mn_2Au and Fe on a Nb(100) substrate capped by a pseudomorphic monolayer of Au via flash annealing. This preserves the long-range crystallographic order and periodicity of Nb [2] while preventing surface oxidation. Layer-by-layer growth of Mn_2Au is monitored in-situ via medium-energy electron diffraction (MEED). Structural analysis is carried out by Auger electron spectroscopy (AES) and low-energy electron diffraction (LEED). After field-cooling, dynamics of the exchange-bias-shifted magnetization loop are studied by Kerr magnetometry and microscopy. Our results highlight the feasibility to expand the range of available substrates to metal single crystals for the growth of Mn_2Au layers.

[1] J. Zelezny, H. Gao, K. Vyborny et al., Phys. Rev. Lett. 113 (2014)
[2] E. Hüger, H. Wormeester, K. Osuch, Surf. Sci. 580 (2005)

MA 47.32 Thu 15:00 Poster D

Impact of ion bombardment on the magnetic proximity effect in Pt/Fe bilayers — •Mika Ossenschmidt[1], Maik Gaerner[1], Varun Vanakalapu[2], Arne Vereijken[2], Arno Ehresmann[2], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]University of Kassel, Germany

KeV-He ion bombardment of thin-film interfaces offers the opportunity to modify the interface properties of thin-film systems, including the roughness σ. In case of magnetic interfaces, the magnetic properties can be altered by low-sputter yield keV light ion bombardment without destroying the thin films, e.g. as shown for exchange-bias systems [1].

We have prepared samples of Pt 4.5nm/Fe 10nm//MgO(001) by sputter deposition and investigated the impact of ion bombardment on the magnetic proximity effect in Pt. The subsequent ion bombardment dose varied from 10^{15} to 10^{17} $1/cm^2$. We measured x-ray resonant magnetic reflectivity [2,3] at the Pt L_3 absorption edge (11.568keV) at room temperature and in air at DESY beamline P09. The fits of the x-ray reflectivity measurements provide a significant difference for the roughness σ of the Pt/Fe interface due to ion bombardment while layer thicknesses, substrate roughness, and surface remained nearly unchanged. The resulting maximum Pt moment at the interface for the sample with ion bombardment is higher than without ion bombardment.

[1] Ehresmann et al., J. Phys. D: Appl. Phys. 38, 801 (2005)
[2] Macke et al., J. Phys.: Condens. Matter 26, 363201 (2014)
[3] Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)

MA 47.33 Thu 15:00 Poster D

Magnon-phonon interactions from first principles — •László Udvardi — Budapest University of Technology and Economics, Budapst, Hungary

Spintronics is an emerging field of recent solid state researches. In spintronics magnons hold great promise for quantum and classical information processing due to excellent scalability, tunability and energy-efficiency of magnonic devices. Among several important aspects of spin waves their interactions with phonons is one of the interesting area. Magnetic systems are often described by classical spin models. The exchange couplings, Dzyaloshinsky-Moriya interactions and magnetic anisotropy parameters appearing in the spin models can be determined from first principles. A recent review [1] discusses the most frequently used ab-initio methods. In point of view of magnon-phonon interactions the change of the exchange interactions against small displacement of the magnetic atoms have crucial importance.

In spirit of torque method we derived formulas for the change of the exchange couplings and magnetic anisotropy parameters with respect of small displacement of the atomic positions by means of multiple scattering theory. We have found a contribution which is not present in a recent paper by Mankovsky et al.[2]. The results are demonstrated on a Fe monolayer on surface of Au(001).

[1] A. Szilva et al., Rev. Mod. Phys. 95,035004 (2023)
[2] S. Mankovsky et al., Phys. Rev. Letter 129,067202 (2022)

MA 48: Members' Assembly

Time: Thursday 18:00–19:00 Location: H 1058

All members of the Magnetism Division are invited to participate.

MA 49: $SrTiO_3$: A Versatile Material from Bulk Quantum Paraelectric to 2D Superconductor III (joint session TT/KFM/MA/O)

Strontium titanate ($SrTiO_3$) is a paradigmatic material that plays an important role in various fields of solid-state physics, surface science and catalysis: The pure bulk phase is a wide-band-gap semiconductor that upon cooling becomes a textbook quantum paraelectric. When slightly doped, $SrTiO_3$ turns into a Fermi-liquid-type metal that becomes superconducting at extremely low charge carrier density. $SrTiO_3$-based surfaces and interfaces host un-conventional electronic states such as quasi-two-dimensional electron liquid, magnetism and superconductivity. Despite intensive studies over the past decades, $SrTiO_3$ continues to reveal surprising new phenomena that challenge the established views on this material. To this end achieving light-induced nonequilibrium states and the recent preparation of a 2D oxide based on $SrTiO_3$ opens new playgrounds for research. This Focus Session will present exciting developments in the study of electronic states that are based on the peculiar properties of $SrTiO_3$.

Please note that this Focus Session comprises four parts: Posters are presented within the TT poster session TT58 (Wed 15:00-18:00, poster area E). Invited talks are compiled in the session TT62 (Thursday, 9:30 to 12:45, H0104), Contributed talks will be presented in sessions TT72 (Thursday 15:00-18:00, H0104) and TT83 (Fri 9:30-12:30, H0104).

Organizers: Rossitza Pentcheva, University of Duisburg-Essen, Marc Scheffler, University of Stuttgart

Time: Friday 9:30–12:30 Location: H 0104

MA 49.1 Fri 9:30 H 0104

High-mobility two-dimensional electron gases based on strain engineered ferroelectric $SrTiO_3$ thin films — •Ruchi Tomar[1], Tatiana Kuznetsova[2], Srijani Mallik[1], Luis M. Vicente-Arche[1], Fernando Gallego[1], Maximilien Cazayous[3], Roman Engel-Herbert[2,4], and Manuel Bibes[1] — [1]Unité Mixte de Physique, CNRS, Thales, Université Paris-Saclay, 91767 Palaiseau, France. — [2]Pennsyvlania State University, University Park, PA 16802, USA. — [3]Laboratoire Matériaux et Phénomènes Quantiques (UMR 7162 CNRS), Université de Paris, 75205 Paris Cedex 13, France. — [4]Paul Drude Institute for Solid State Electronics, Leibniz Institute within Forschungsverbund Berlin eV, Hausvogteiplatz 5-7, 10117, Berlin, Germany.

Two-dimensional electron gases (2DEGs) based on the quantum paraelectric $SrTiO_3$ display fascinating properties such as large electron mobilities, superconductivity, and efficient spin-charge interconversion owing to their Rashba spin-orbit coupling. Here, we use oxide molecular beam epitaxy to grow high-quality strain-engineered $SrTiO_3$ films that are ferroelectric up to 170 K. We then generate a 2DEG by sputtering a thin Al layer and demonstrate an increase in mobilities compared to earlier literature. Furthermore, through Raman spectroscopy and magneto-transport measurements, we show that the ferroelectric character is retained after 2DEG formation. These results thus qualify our samples as ferroelectric 2DEGs up to temperatures well above previous results based on Ca-$SrTiO_3$ substrates, opening the way towards ferroelectric 2DEGs operating at room temperature.

MA 49.2 Fri 9:45 H 0104

Two-dimensional electron liquids at truly bulk-terminated $SrTiO_3$ — •Igor Sokolović[1,2], Eduardo B. Guedes[3], Thomas van Waas[4], Samuel Poncé[4,5], Craig M. Polley[6], Michael Schmid[2], Ulrike Diebold[2], Milan Radović[3], Martin Setvín[2,7], and J. Hugo Dil[3,8] — [1]Institute of Microelectronics, TU Wien, Vienna, Austria — [2]Institute of Applied Physics, TU Wien, Vienna, Austria — [3]Photon Science Division, PSI, Villagen, Switzerland — [4]ETSF, Institute of Condensed Matter and Nanosciences, UCLouvain, Louvain-la-Neuve, Belgium — [5]WEL Research Institute, Wavre, Belgium — [6]MAX IV laboratory, Lund University, Lund, Sweden — [7]Faculty of Mathematics and Physics, Charles University, Prague , Czech Republic — [8]Institut de Physique, ÉPFL, Lausanne, Switzerland

A truly bulk-terminated $SrTiO_3$(001) surface prepared by cleaving *in situ* was investigated with angle-resolved photoemission spectroscopy (ARPES) and noncontact atomic force microscopy (ncAFM). The (1×1) $SrTiO_3$(001) surfaces were achieved through our cleaving procedure that exploits the strain-induced ferroelectric transition in $SrTiO_3$, and provides both possible surface terminations, TiO_2 and SrO. Each hosts a specific two-dimensional electron liquid (2DEL): the first with split and the other with degenerate bands. The origin of the 2DELs and the band-splitting mechanisms are elucidated by correlating the observed reciprocal- and real-space electronic and atomic structure.

MA 49.3 Fri 10:00 H 0104

Low-energy excitations at $SrTiO_3$(001) surfaces in absence and presence of a two-dimensional electron gas — •Hannes Herrmann, Anne Oelschläger, and Wolf Widdra — Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

The low-energy excitations of $SrTiO_3$, a large-bandgap oxide perovskite, are dominated by phonons and phonon polaritons. At the surface they couple to dipole-active surface phonon polaritons that are bound to the $SrTiO_3$-vacuum interface. These excitations can be addressed by surface vibrational spectroscopy techniques as, e.g., high-resolution electron energy loss spectroscopy (HREELS).
Here we will present HREELS studies that identify all $SrTiO_3$(001) dipole-active excitations, including their specific line shapes and will discuss the electron-phonon coupling to a two-dimensional electron gas. The latter are prepared with variable charge-carrier concentrations either by annealing under ultrahigh-vacuum condition or by growth of an ultrathin layers of EuO on top. With formation of the 2DEGs, the discrete surface phonon polaritons couple to the electron-hole pair continuum as is witnessed by a substantial line broadening and asymmetric Fano-like line shapes. A quantitative description that accounts for all details of the line shape paves the way for an in-situ analysis of the 2DEG charge carrier dynamics.

MA 49.4 Fri 10:15 H 0104

Confined ionic-electronic systems based on $SrTiO_3$ — •Felix Gunkel, Marcus Wohlgemuth, Moritz L. Weber, and Regina Dittmann — Peter Gruenberg Institute, Forschungszentrum Juelich

$SrTiO_3$ reflects a a prototype ionic-electronic oxide, in which the physical properties are significantly affected by the ionic defect structure. [Gunkel et al., APL 2020] At the same time, spatial confinement of electronic charge carries led to unexpected electronic and magnetic phenomena, including 2DEG formation, magnetoresistance and localization phenomena. Here we will discuss, how spatial confinement also affects the ion-dynamics and defect-equilibria of SrTiO3, yielding interfacial defect structures and ion-dynamics that significantly differ from the bulk. [Rose et al., Adv. Mater. (2023); Weber et al., Nature Mater., to be published (Jan 2 2024)]. New opportunities to tailor such confined ionic-electronic systems arise from synthesis advances in generating transferable, free-standing $SrTiO_3$ sheets. These reflect ideally-confined nanosheets of $SrTiO_3$ and can serve as model system for ionic-electronic confinement phenomena as well as template for the synthesis of functional bilayer structures. We discuss the state-of-the-art of controlled bilayer synthesis and derive the required finite-size corrections in the thermodynamic description of the defect chemistry of $SrTiO_3$, indicating that the average reduction enthalpy of $SrTiO_3$ can be effectively reduced via confinement.

MA 49.5 Fri 10:30 H 0104

Origin of spin-polarized 2DEG at the $EuTiO_3$(001) surface and $LaAlO_3/EuTiO_3/SrTiO_3$(001) interface — •Manish Verma and Rossitza Pentcheva — Department of Physics, Universität Duisburg-Essen

Since the discovery of a two-dimensional electron gas (2DEG) at the interface between the $LaAlO_3$ and $SrTiO_3$ band insulators, studies on oxide surfaces and interfaces uncovered an intriguing and rich physics, such as possible magnetism in 2DEG. Using density functional theory with an on-site Coulomb repulsion term U, we find a spin-polarized 2DEG at the $EuTiO_3$(001) surface arising from the interplay of ferromagnetic (FM) order of Eu-4f magnetic moments and the localization of electrons released from oxygen divacancies at the surface Ti sites, in agreement with in situ high-resolution angle-resolved photoemission [1]. The 2DEG at the $LaAlO_3/EuTiO_3/SrTiO_3$(001) interface is formed due to the polar discontinuity. The spin-polarization is due to the FM exchange interaction between Eu 4f and Ti 3d states and steers the occupation of d_{xz}/d_{yz} orbitals [2].
[1] R. Di Capua *et al.*, Phys. Rev. Research **3** (2021) L042038
[2]. R. Di Capua *et al.*, npj Quantum Mater. **7** (2022) 41

MA 49.6 Fri 10:45 H 0104

A multiferroic STO-based 2D-electron gas — •Marco Salluzzo[1], Yu Chen[1], Martando Rath[1], Daniela Stornaiuolo[2], Julien Brehin[3], Manuel Bibes[3], Julien Varignon[4], and Cinthia Piamonteze[5] — [1]Cnr-Spin Complesso Monte S. Angelo via Cinthia 80126, Napoli, Italy — [2]Università "Federico II" di Napoli, Dipartimento di Fisica "Ettore Pancini", Complesso Monte S. Angelo via Cinthia 80126, Napoli, Italy — [3]Unité Mixte de Physique, CNRS, Thales, Université Paris Saclay, Palaiseau, France — [4]Crismat, CNRS , Ensicaen, Normandie Université, Caen, France — [5]Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland.

The fabrication of artificial materials combining different functional properties is a powerful method to create novel quantum states. Here we demonstrate the realization of a 2D electron gas exhibiting a coexistence of ferroelectric and ferromagnetic order parameters, by heteroepitaxy.

The novel 2DEG is realized by inserting few unit cells of the antiferromagnetic insulator $EuTiO_3$ between a $LaAlO_3$ band insulating thin film (10 unit cells) and a Ca-doped $SrTiO_3$ single crystal.

By using Ti-$L_{2,3}$ and Eu $M_{4,5}$ edges x-ray linear dichroism and x-ray magnetic circular dichroism, we provide evidences of a switchable polarization, non-volatile tuning of Ti3d orbital splitting, and of a modulation of Eu-4f magnetic moment of the 2DEG by the FE-polarization[1]. The result is of interest for quantum spin-orbitronic applications.
[1] J. Bréhin et al., Nat. Phys. 19 (2023) 823

MA 49.7 Fri 11:00 H 0104

Magnetotransport properties of a spin polarized STO-based 2D electron system tuned by visible light — Maria D'Antuono[1,2], Yu Chen[2], Roberta Caruso[1,2,3], Benoit Jouault[4], Marco Salluzzo[2], and •Daniela Stornaiuolo[1,2] — [1]Department of Physics, University of Naples Federico II, Italy. — [2]CNR-SPIN, Naples, Italy. — [3]Condensed Matter Physics and Materials Science Division, Brookhaven National Laboratory, NY, USA. — [4]Laboratoire Charles Coulomb, CNRS,Université de Montpellier, France

Two-dimensional electron systems (2DES) developing in STO-based heterostructures possess a wide range of properties which are largely tunable thanks to the systems band structure and carrier density. In $LaAlO_3/EuTiO_3/SrTiO_3$ (LAO/ETO/STO) heterostructure, for instance, the charge carriers, above a critical value, start to fill Ti-3d bands with $d_{xz,yz}$ character, leading to the stabilization of a ferromagnetic order of Ti and Eu magnetic moments, and to a spin polarization of the 2DES. In this work we show that such mechanism can be achieved not only using electric field effect, but also using visible light irradiation. Furthermore, the analysis of the Anomalous Hall effect and of magnetocodnuctance curves demonstrate that visible light irradiation leads to enhanced stabilization of ferromagnetic correlations in the 2DES. Our results establishs the combined use of visible light and gate voltage as a straightforward way to access unexplored regions of the LAO/ETO/STO 2DES phase diagram.

15 min. break

MA 49.8 Fri 11:30 H 0104

All-electrical measurement of the spin-charge conversion effect in nanodevices based on $SrTiO_3$ two-dimensional electron gases — •Fernando Gallego[1], Felix Trier[1,2], Srijani Mallik[1], Julien Brehin[1], Sara Varotto[1], Luis Moreno[1], Tanay Gosavy[3], Chia-Ching Lin[3], Jean-René Coudevylle[4], Lucía Iglesias[1], Fèlix Casanova[5,6], Ian Young[3], Laurent Vila[7], Jean-Philippe Attané[7], and Manuel Bibes[1] — [1]Unité Mixte de Phys, CNRS-Thales, Univ. Paris-Saclay, 91767 Palaiseau, France. — [2]Dept of Energy Conservation and Storage, Univ. of Denmark, 2800 Kgs. Lyngby, Denmark. — [3]Comp. Res. Intel Corp., Hillsb., OR 97124, USA. — [4]Centre de Nanosciences et de Nanotech., CNRS, Université Paris-Sud, Université Paris-Saclay, France. — [5]CIC nanoGUNE BRTA, 20018 Donostia, Spain. — [6]IKERBASQUE, Basque Foundation for Science, 48009 Bilbao, Spain. — [7]Univ. Grenoble Alpes, CNRS, CEA, SPINTEC, Grenoble, France.

We report all-electrical spin-injection and spin-charge conversion experiments in nanoscale devices harnessing the inverse Edelstein effect of $SrTiO_3$ 2DEGs. We have designed, patterned and fabricated nanodevices in which a spin current injected from a cobalt layer into a $LaAlO_3/SrTiO_3$ 2DEG is converted into a charge current. We optimized the spin-charge conversion signal by back-gating. We further disentangled the inverse Edelstein contribution from spurious effects. The combination of non-volatility and high energy efficiency of these devices could potentially lead to new technology paradigms for beyond-CMOS computing architectures.

MA 49.9 Fri 11:45 H 0104

Effect of confinement and coulomb interactions on the electronic structure of the (111) $LaAlO_3/SrTiO_3$ interface — •Mattia Trama[1,2,3], Vittorio Cataudella[4,5], Carmine Antonio Perroni[4,5], Francesco Romeo[1], and Roberta Citro[1,2] — [1]Universitá degli Studi di Salerno, Fisciano, Italy — [2]INFN Sezione di Napoli, Naples, Italy — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, Germany — [4]Universitá degli Studi di Napoli Federico II, Naples, Italy — [5]CNR-SPIN Napoli Unit, Naples, Italy

A tight-binding supercell approach is used for the calculation of the electronic structure of the (111) $LaAlO_3/SrTiO_3$ interface. The confinement potential at the interface is evaluated solving a discrete Poisson equation by means of an iterative method. In addition to the effect of the confinement, local Hubbard electron-electron terms are included at the mean-field level within a fully self-consistent procedure. The calculation carefully describes how the two dimensional electron gas arises from the quantum confinement of electrons near the interface due to the band bending potential. The resulting electronic sub-bands and Fermi surfaces show full agreement with the electronic structure determined by angle-resolved photoelectron spectroscopy experiments. In particular, we analyse how the effect of local Hubbard interactions change the density distribution over the layers from the interface to the bulk. Interestingly, the two-dimensional electron gas at the interface is not depleted by local Hubbard interactions which indeed induce an enhancement of the electron density between the first layers and the bulk.

MA 49.10 Fri 12:00 H 0104

Enhanced Non-linear Response by Manipulating the Dirac Point in the (111) $LaTiO_3/SrTiO_3$ Interface — •Yoram Dagan, Gal Tuvia, Amir Burshtein, Itai Silber, Amnon Aharony, Ora Entin-Wohlman, and Moshe Goldstein — School of Physics and Astronomy, Tel Aviv University

Tunable spin-orbit interaction (SOI) is an important feature for future spin-based devices. In the presence of a magnetic field, SOI induces an asymmetry in the energy bands, which can produce non-linear transport effects ($V \sim I^2$). Here, we focus on such effects to study the role of SOI in the (111) $LaTiO_3/SrTiO_3$ interface. This system is a convenient platform for understanding the role of SOI since it exhibits a single-band Hall-response through the entire gate-voltage range studied. We report a pronounced rise in the non-linear longitudinal resistance at a critical in-plane field H_{cr}. This rise disappears when a small out-of-plane field component is present. We explain these results by considering the location of the Dirac point formed at the crossing of the spin-split energy bands. An in-plane magnetic field pushes this point outside of the Fermi contour, and consequently changes the symmetry of the Fermi contours and intensifies the non-linear transport. An out-of-plane magnetic field opens a gap at the Dirac point, thereby significantly diminishing the non-linear effects. We propose that magnetoresistance effects previously reported in $SrTiO_3$-based interfaces could be comprehended within our suggested scenario.

MA 49.11 Fri 12:15 H 0104

Tunable 2D Electron- and 2D Hole States Observed at Fe/$SrTiO_3$ Interfaces — •Pia Maria Düring[1], Paul Rosenberger[1,2], Lutz Baumgarten[3], Fatima Alarab[4], Frank Lechermann[5], Vladimir N. Strocov[4], and Martina Müller[1] — [1]FB Physik, Universität Konstanz, 78457 Konstanz — [2]TU Dortmund, 44221 Dortmund — [3]FZ Jülich, PGI-6, 52425 Jülich — [4]PSI, SLS, CH-5232 Villingen — [5]TP III, RU Bochum, 44780 Bochum

Oxide electronics provide the key concepts and materials for enhancing silicon-based semiconductor technologies with novel functionalities. However, a crucial property of semiconductor devices remains undisclosed in their oxide counterparts: the ability to set or even switch between negatively (n) charged electrons or positively (p) charged holes. Using resonant angle-resolved photoelectron spectroscopy, we provide direct evidence for individually emerging n- or p-type 2D band dispersions in $SrTiO_3$ (STO)-based heterostructures [1]. The key to setting the carrier character is the oxidation state of a Fe-based interface layer: For Fe and FeO, hole bands emerge in the empty band gap region of STO, while for Fe_3O_4 overlayers, an 2D electron system (2DES) is formed. Unexpected oxygen vacancy characteristics arise for the hole-type interfaces, which as of yet had been exclusively assigned to the emergence of 2DESs. In general, this study unveils the potential to seamlessly alter the conductivity type at STO interfaces by manipulating the oxidation state of a redox overlayer.

[1] P. M. Düring et al., Adv. Mater. (accepted)

MA 50: Focus Session: Emerging Magnetic Phenomena from Chiral Phonons II (joint session MA/TT)

Contemporary efforts in spintronics focus on utilizing and controlling electronic angular momentum for possible applications in data storage and processing. Only recently, an alternative has arisen in the form of angular momentum generated by circularly polarized (chiral) phonons. Chiral phonons have been shown to lead to a variety of novel magnetic phenomena, including a phonon Hall, phonon Einstein-de Haas, phonon Barnett, and phonon Zeeman effect. Phonon angular momentum can be utilized to control the magnetic state of solids and even to induce magnetization in nonmagnetic materials. These discoveries make the angular momentum of chiral phonons a promising tool for the control of magnetic materials and an emerging quantity of interest for spintronic applications. The goal of this focus session is to highlight topical research on novel magnetic phenomena arising from chiral phonons and to connect this rapidly developing field to the broader audience working in magnetism and spintronics.

Coordinators: Sebastian T. B. Goennenwein, Universität Konstanz, sebastian.goennenwein@uni-konstanz.de Ulrich Nowak, Universität Konstanz, ulrich.nowak@uni-konstanz.de

Time: Friday 9:30–11:30 Location: H 1058

MA 50.1 Fri 9:30 H 1058

Born effective charges in insulators and metals — •Paolo Fachin, Francesco Macheda, and Francesco Mauri — Sapienza, Università di Roma, Italia

The Born effective charges quantify the coupling of phonons with light, allowing to describe experimental spectra of crystals in infrared spectra. While in insulators the electrical polarization is well defined and the Born Effective charges are described in a Berry phase formulation in the context of the modern theory of polarization[1], in metals this quantity is more challenging to deal with. There are two different limits, the static [2] and the dynamical [1][3] one, concurring in the determination of the vibrational features in a combination depending on the phonon frequency and linewidth ratio [4]. The nature of these two limits is clarified using a low energy model for graphene compared with ab initio simulations. The effect of the recently predicted [5][6] intrinsic chiral phonons in crystals can be detected in infrared experiments in a way that is described by the Born effective charges.

[1] Bistoni,Mauri et al., 2D Materials, 6, 045015 (2019)
[2] Macheda, Barone and Mauri, Phys.Rev.Lett.,129(18),185902(2022)
[3] Dreyer,Coh, and Stengel, Phys. Rev. Lett., 128, 095901 (2022)
[4] Marchese, Macheda, Mauri and al., Nat. Phys. (2023)
[5] Bistoni, Mauri, and Calandra, Phys.Rev.Lett. 126,225703 (2019)
[6] Saparov, Niu et al., Phys. Rev. B 105, 064303 (2022)

MA 50.2 Fri 9:45 H 1058

Magnon-phonon coupling in $Co_{25}Fe_{75}$ thin film/crystalline substrate heterostructures — •J. Weber[1,2], M. Müller[1,2], F. Engelhardt[3,4,5], V. Bittencourt[6], T. Luschmann[1,2,7], M. Cherkasskii[5], S.T.B. Goennenwein[8], S.V. Kusminskiy[5,3], S. Geprägs[1], R. Gross[1,2,7], M. Althammer[1,2], and H. Huebl[1,2,7] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]School of Natural Sciences, Technical University of Munich, Garching, Germany — [3]Max Planck Institute for the Science of Light, Erlangen, Germany — [4]Department of Physics, University Erlangen-Nuremberg, Erlangen, Germany — [5]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [6]ISIS (UMR 7006), Université de Strasbourg, Strasbourg, France — [7]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [8]Department of Physics, University of Konstanz, Konstanz, Germany

The coupling between the quantized excitations of the spin system (magnons) and the lattice (phonons) regained interest due to potential applications in quantum devices. Here, we report the coherent excitation of elastic waves in a metallic ferromagnetic $Co_{25}Fe_{75}$ thin film by driving its Kittel modes, leading to the excitation of transverse acoustic phonons in the substrate forming a bulk acoustic wave resonator. Our results agree well with model calculations based on the magnetic and acoustic properties of the magnetic and elastic subsystems and allow to determine the effective magnetoelastic coupling strength.

MA 50.3 Fri 10:00 H 1058

Light induced magnetization in $SrTiO_3$ — •Natalia Shabala and R. Matthias Geilhufe — Department of Physics, Chalmers University of Technology, 412 96 Göteborg, Sweden

Dynamical multiferroicity refers to magnetization of a material caused by a temporally varying polarization [1]. Such phenomena can be light-induced. For example, Kerr-effect measurements on THz-pumped $SrTiO_3$ (STO) reveal significant magnetic moments in the sample of about 0.1 Bohr magneton per unit cell, while $SrTiO_3$ itself is nonmagnetic [2]. Moreover, this value is significantly larger than the one expected from a circularly moving charge argument. We attempt to understand this discrepancy by finding a connection between magnetization resulting from optically driven chiral phonons and Berry connection. By extending the formalism of inverse Faraday effect to phonons and applying modern theory of polarization, we hope to develop a better understanding of the large difference between theoretical and experimental values of light induced magnetization. In the prospect of "phonon-enabled technology", we apply our formalism to investigate a Hall effect in graphene/STO, mediated by light-induced chiral phonons in the STO substrate. We find that a laser field strength of 0.1 MV/m and a current of 1 mA will cause a transverse electric field of about 40 nV, which can be measured in state-of-the-art experiments.

[1] D. M. Juraschek et al., "Dynamical multiferroicity", *Phys. Rev. Mater.*, 1.1 (2017): 014401
[2] M. Basini et al., "Terahertz electric-field driven dynamical multiferroicity in $SrTiO_3$", *arXiv preprint arXiv:2210.01690* (2022)

MA 50.4 Fri 10:15 H 1058

Creating and observing elliptically polarized coherent optical shear phonons in graphite — Arne Ungeheuer, Mashood T. Mir, Ahmed S. Hassanien, Lukas Nöding, Thomas Baumert, and •Arne Senftleben — Institut für Physik, Universität Kassel

We present a scheme to create circularly or elliptically polarized coherent phonons of the degenerate inter-layer shear mode in graphite. The approach utilizes the time-delayed excitation of two coherent phonons linearly polarized in perpendicular directions by femtosecond laser pulses. We observe the resulting elliptically polarized coherent phonon using ultrafast electron diffraction [1], where they create a unique signature that allows us to determine the phonon's ellipticity and sense of rotation. Analyzing the atomic motion in the crystal, we find that the atoms in adjacent layers circulate in the same direction in a Hula hoop fashion. In magnetic materials, such elliptically polarized phonons can create a transient magnetization in an atomistic version of the Barnett effect [2].

[1] C. Gerbig, et al. *New J. Phys.* **17**, 043050 (2015).
[2] T. F. Nova, et al. *Nature Phys.* **13**, 132–136 (2017).

MA 50.5 Fri 10:30 H 1058

Chirality of spin and orbital dynamics in laser-induced demagnetization — •Junjie He — Charles University, Prague, Czech Republic

Despite spin (SAM) and orbital (OAM) angular momentum dynamics are well-studied in demagnetization processes, their components receive less focus. Here, we utilize the real-time ab initio theory to unveil significant x and y components of SAM and OAM induced by circularly left (σ+) and right (σ-) polarized laser pulse in Ferromagnetic metals. Our results show that the magnitude of OAM is an order of magnitude larger than that of SAM, highlighting a stronger optical response from the orbital degrees of freedom of electrons compared to spin. Additionally, we observe a marked dependency of the oscillations of the x and y components on the optical helicity. Intriguingly, σ+ and σ- pulses induce chirality in the precession of SAM and OAM, respectively, with clear associations with laser frequency and duration. Our results could be important to understand the polarized phonon in the demagnetization process.

MA 50.6 Fri 10:45 H 1058

Ultrafast symmetry breaking with multicolor chiral phonons — •Omer Yaniv and Dominik Juraschek — Tel Aviv University, Tel Aviv, Israel

In the field of ultrafast dynamics, terahertz pulses stand out as powerful tools capable of initiating coherent vibrational motions in crystal lattices. Circularly or elliptically polarized pulses can excite chiral phonons, which are the collective vibrational patterns of circular or elliptical orbital motions of atoms around their equilibrium lattice positions. Such phonons carry angular momentum and are able to generate magnetic fields leading to a varying range of phenomena. Our study explores the coherent driving of chiral phonons using multicolor laser pulses. Such driving allows us to generate different types of magnetic patterns. We focus on IR-active optical degenerate phonons in CsPbF3 with frequencies at 1.8 THz and 3.6 THz and look at three different features of this multicolor phonon driving. We dynamically induce inversion symmetry breaking in the centrosymmetric lattice structure. This can give rise to nonlinear phenomena, such as second harmonic generation (SHG). Additionally, we show the generation of atomic eight-curve motion, which leads to the generation of spatially distinct alternating phononic angular momentum. This gives rise to an antiferromagnetic pattern of the dynamical phonon magnetic moment. Furthermore, our findings indicate that coherent excitation can lead to the formation of new symmetries, such as a 3-fold rotation, arising from atomic cloverleaf motion. We expect our predictions to be realizable with state-of-the-art pulse shaping techniques.

MA 50.7 Fri 11:00 H 1058

Chiral phonons as dark matter detectors — •Carl Romao[1], Riccardo Catena[2], Nicola Spaldin[1], and Marek Matas[1] — [1]Department of Materials, ETH Zurich, CH-8093 Zurich, Switzerland — [2]Department of Physics, Chalmers University of Technology, SE-412 96 Goteborg, Sweden

We have proposed a method for detecting single chiral phonons using magnetometers. This would allow chiral phonons to be used as dark-matter detectors capable of exploring a multitude of unprobed dark-matter candidates. Metal*organic frameworks are potential candidate detector materials, as their flexibility yields low-energy chiral phonons with measurable magnetic moments, and their anisotropy leads to directional sensitivity, which mitigates background contamination. InF3(4,4'-bipyridine) has been identified as a candidate material; sensing of its phonon magnetic moments would extend detector reach by orders of magnitude below current limits.

MA 50.8 Fri 11:15 H 1058

Nuclear boost to pseudomagnetic fields from quantum geometry — •Lennart Klebl[1], Arne Schobert[1], Giorgio Sangiovanni[2], Alexander V. Balatsky[3,4], and Tim O. Wehling[1,5] — [1]Universität Hamburg, Germany — [2]Universität Würzburg, Germany — [3]University of Connecticut, Storrs, USA — [4]Nordita, Stockholm University and KTH Royal Institute of Technology, Stockholm, Sweden — [5]The Hamburg Centre for Ultrafast Imaging, Germany

Recent experiments demonstrate precise control over coherently excited phonon modes using high-intensity terahertz lasers, opening new pathways towards dynamical, ultrafast design of magnetism in functional materials. While in qualitative agreement with the observed dynamics in experiments, the theoretically predicted magnetic field strengths of circularly polarized phonon modes lack three orders of magnitude. In this work, we put forward a coupling mechanism based on electron-nuclear quantum geometry. This effect is rooted in the adiabatic evolution of the electronic wavefunction under a circular evolution of nuclear coordinates. The excitation pulse then induces a transient level splitting between electron orbitals that carry angular momentum. When converted to effective magnetic fields, values on the order of tens of Teslas are easily reached. We give criteria under which the evolution of nuclear degrees of freedom can be described adiabatically in the electronic sector and find that in the perovskite $SrTiO_3$, the adiabatic regime is in experimental reach.

MA 51: Caloric Effects in Ferromagnetic Materials

Time: Friday 9:30–13:15 Location: H 2013

Invited Talk MA 51.1 Fri 9:30 H 2013

Functional and microstructural design of multicaloric Heusler alloys — •Franziska Scheibel[1], Lukas Pfeuffer[1], Andreas Taubel[1], Christian Lauhoff[2], Philipp Krooss[2], Thomas Niendorf[2], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Darmstadt, Germany — [2]University of Kassel, Kassel, Germany

Due to their first-order magnetostructural transition (FOMST), Ni-Mn-based Heusler alloys exhibit a variety of exploitable phenomena, such as magneto-, elasto-, and multicaloric effects. Functional performance and FOMST can be tailored by compositional and microstructural design. Besides a high cyclic caloric effect as a key requirement for solid-state refrigeration, shaping, functional fatigue, and scalability are key criteria when the material is to reach application. The mechanical strength and cyclic stability can be improved by grain refinement or precipitate formation through doping. By combining the two, it was even possible to achieve a cycle stability of more than 16000 cycles. [1]. Powder-based techniques (such as additive manufacturing (AM), spark plasma sintering, or hot compaction), can be used to achieve scalability and formability. We investigated the entire processing chain from gas-atomized, spherical powder to post-processed parts. In particular, this is important for AM to optimize microstructure, FOMST, and caloric effect [2,3]. We thank the ERC Adv. Grant "CoolInnov", and the CRC/TRR 270 "HoMMage" for funding.

[1] L. Pfeuffer et al., Acta Mater. 221, 117390 (2021)
[2] F. Scheibel et al., Adv. Eng. Mater., 2200069 (2022)
[3] F. Scheibel et al., MTLA 29, 101783 (2023)

MA 51.2 Fri 10:00 H 2013

Impact of spin-entropy on the thermoelectric properties of a 2D magnet — •Alessandra Canetta — Institute of Condensed Matter and Nanosciences, Université catholique de Louvain (UCLouvain), 1348 Louvain-la-Neuve, Belgium

The heat-to-charge conversion efficiency of thermoelectric materials is closely linked to the entropy per charge carrier. Therefore, finding ways to increase this entropy could lead to new design strategies for highly efficient energy harvesters or spot-cooling devices. To this end, magnetic materials are a promising choice because their carrier entropy is boosted by a spin degree of freedom. To study this capability, a model magnetic system with high tunability of its magnetic order is required. The A-type antiferromagnet CrSBr fits these requirements and we investigate how spin entropy impacts heat-to-charge conversion in this 2D layered magnet. We perform simultaneous measurements of electrical conductance and thermocurrent while changing magnetic order using temperature and magnetic field as tuning knobs. We find a 10% decrease of the Seebeck coefficient when establishing antiferromagnetic order. We further reveal a drastic reduction of the Seebeck coefficient by one order of magnitude below a temperature of 40 K, which we attribute to a drop in spin entropy due to a spin-freezing process. Our results highlight the sizeable impact of spin entropy on thermoelectric properties and suggest thermoelectric measurements as a sensitive tool to study magnetic phase transitions in low-dimensional magnets.

MA 51.3 Fri 10:15 H 2013

A temperature model for the Magnetic Hyperthermia — •Viorica Monica Moisiuc and Iordana Astefanoaei — Faculty of Physics, Alexandru Ioan Cuza University of Iasi, Romania

Magnetic hyperthermia is an important medical technique which uses therapeutic heat from the magnetic nanoparticles when an external high frequency magnetic field was applied. The temperature developed within tumoral tissues by the nanoparticles can be controlled by the fine control of the magnetic field parameters: i) frequency and ii) the amplitude of the field. In the last years, this topic receives a special attention in all theoretical and experimental studies. The spatial distribution of magnetic nanoparticles in the tumoral tissue significantly influences the temperature during this treatment. In this work, a concentric tissue geometry (tumoral tissue surrounded by the healthy tissue) was considered. The magnetic nanoparticles with different properties are distributed non-uniformly in the tumor tissue. The thermal response of the tumoral tissue heated by the magnetic nanoparticles in a high-frequency electromagnetic field was analyzed by the analytical and numerical computations. Bioheat transfer equation was solved to obtain the temperature field within tissues. The spatio-temporal evolution of the temperature in correlation with the nanoparticles volume fraction was analyzed for different types of magnetic particles injected into the tumor tissue. The mathematical model allows the computation of the hyperthermic temperature for nanoparticle systems with the following particularities: different concentrations, sizes and magnetic and thermal properties (maghemite, magnetite).

MA 51.4 Fri 10:30 H 2013

Measuring the Anomalous Ettingshausen effect in the magnetic Weyl semimetal Co_2MnGa — •Mohammadali Razeghi and Pascal Gehring — IMCN/NAPS, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

Magnetic Weyl semimetals (MWSMs) have been praised for their exceptional electrical transport properties. Often overlooked, energy and heat transport properties remain to be investigated. Especially coupled properties, such as heat to charge conversion, are expected to be enhanced by topological effects in MWSMs. The Heusler alloy Co_2MnGa has been reported to show MWSM state at room temperature with large anomalous Hall and Nernst coefficients.

In this work, we explore the cooling capability of Co_2MnGa devices using Scanning Thermal Microscopy (SThM). SThM allows us to locally map temperature variations and to trigger temperature driven electrical transport effects in micropatterned Co_2MnGa devices. We explore thermomagnetic and thermoelectric effects and their interplay with geometry, charge density and magnetic field. In particular we observe a pronounced anomalous Ettingshausen effect and reveal a strong contribution from band topology to its magnitude. We furthermore quantify the cooling and heating efficiency of the topological alloy and assess its potential for realization of heat management devices.

MA 51.5 Fri 10:45 H 2013

Multicaloric effect of powder-in-tube Heusler material — •T. Niehoff[1,2], L. Beyer[3,4], C. Salazar Mejia[1], T. Gottschall[1], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [4]TU Bergakademie Freiberg, Germany

Research on magnetocaloric materials with first-order phase transitions typically focuses on reducing their hysteresis. However, in this presentation, we will discuss an alternative approach by capitalizing on the width of the hysteresis to enhance the cooling performance through the synergistic utilization of multiple caloric effects. The fine tuning of the hysteresis is achieved through the rational substitution of appropriate quantities of Fe and Co within the Ni-Mn-Sn Heusler alloy. In addition, the powder-in-tube method is employed to further enhance performances such as mechanical stability, hysteresis, and the magnetocaloric effect itself. To comprehensively investigate the properties and mechanical stability of the material, we conducted stress-strain measurements and adiabatic temperature changes for different initial temperatures. This analysis was performed under varying uniaxial loads within pulsed magnetic fields, reaching up to 50 T.

MA 51.6 Fri 11:00 H 2013

Direct measurements of the adiabatic temperature change in a holmium single crystal using high magnetic fields — •E. Bykov[1], C. Salazar Mejia[1], T. Gottschall[1], J. Wosnitza[1,2], M. D. Kuz'min[3], Y. Mudryk[4], and D. L. Schlagel[4] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Aix-Marseille Université, IM2NP, Marseille, France — [4]Ames Laboratory, U.S. Department of Energy, Iowa State University, Ames, USA

Holmium stands out as an extraordinary magnetocaloric substance due to one of the most substantial magnetic moments found in the periodic table. Its magnetic behavior under temperature and magnetic field variation is intricate, as reflected in a complex phase diagram featuring paramagnetic, helicoidal, conical, fan, spin-slip, and ferromagnetic phases. Even with field variations of 5 T along its easy axis, holmium exhibits a robust magnetocaloric effect, showcasing ΔT_{ad} of approximately 5 K and $\Delta S_T \approx$ -10 J kg^{-1} K^{-1} across a wide temperature span from 20 to 100 K. This positions holmium as a promising material for refrigeration in an active magnetic regenerator system, particularly for applications such as natural gas and hydrogen liquefaction. We present the results of a comprehensive study of single-crystalline holmium in fields up to 60 T.

15 min. break

MA 51.7 Fri 11:30 H 2013

High throughput approach for finding magnetocaloric materials — Rafael Martinho Vieira[1], Sagar Ghorai[2], Olle Eriksson[1], and •Heike C. Herper[1] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Functional Materials, TU Darmstadt, Germany

After several decades of research, the pool of materials suitable for room-temperature refrigeration is still very limited. Materials with magnetostructural phase transition (MST) are possible candidates for magnetocaloric materials. MnNiSi-based systems undergo a structural phase transition and have the potential for MST. We show that an MST can be reached by Fe and Al doping and for Mn1-xFexNiSi0.95Al0.5 we observe a giant magnetocaloric effect at room temperature. [(https://doi.org/10.48550/arXiv.2307.00128)] By combining experiments with ab initio theory and spin dynamics methods we could show that the key to the large magnetocaloric response lies in the coexistence of the two magnetically very different phases at low temperatures. Based on the findings for MnFeNiSiAl we designed a high-throughput search method to identify candidate phases with MST. Big data searches were combined with first-principles calculations and spin dynamics simulations. [1] About 20 systems with several polymorphs were found. Out of this group, several candidates show potential for an MST near room temperature. Their magnetic properties have been studied in our theoretical approach and will be discussed as well as the expected magnetocaloric performance.

[1] Journal of Alloys and Compounds 857, 157811(2021)

MA 51.8 Fri 11:45 H 2013

Ab initio Quantification of Electronic and Magnetoelastic Mechanisms of First-order magnetic phase transitions — •Eduardo Mendive Tapia[1], Lluís Mañosa[1], Aleix Abadia-Huguet[1], Enric Stern Taulats[1], Marius Costache[1], Benedikt Eggert[2], Mehmet Acet[2], Mihai Sturza[3], Holger Kohlmann[3], Christopher Patrick[4], Tilmann Hickel[5], Jörg Neugebauer[5], and Julie Staunton[6] — [1]University of Barcelona, Spain — [2]Universität Duisburg-Essen, Germany — [3]Universität Leipzig, Germany — [4]University of Oxford, UK — [5]MPIE, Düsseldorf, Germany — [6]University of Warwick, Coventry, UK

While magnetovolume coupling is a well-known mechanism driving first-order magnetic phase transitions [1], purely electronic sources [2,3] have a long, subtle history and remain poorly understood. We present an ab initio disordered local moment theory to quantify electronic and magnetoelastic effects [4] underlying the magnetic phase transitions of two different caloric materials: the famous La-Fe-Si compound [3] and a van der Waals Cr2Fe2Te6 crystal [5]. Results in very good agreement with experiment explaining the ab initio origin of the first and second-order nature of their transitions will be shown, together with recent experiments focused on multicaloric effects in Cr2Fe2Te6.

[1] C. P. Bean and D. S. Rodbell, Phys. Rev. 126, 104 (1962)
[2] E. P. Wolfarth and P. Rhodes, Phil. Magazine, 7:83, 1817 (1962)
[3] A. Fujita et al., Phys. Rev. B 65, 014410 (2001)
[4] E. Mendive-Tapia, et al., J. Phys. Energy 5, 034004 (2023)
[5] C. Gong, et al., Nature 546, 265 (2017)

MA 51.9 Fri 12:00 H 2013

Magnetocaloric effect in (La, Ce)(Fe, Si, Mn)$_{13}$ with tunable, low transition temperature — •M. Strassheim[1,2], C. Salazar-Mejia[1], L. Beyer[3,4], J. Wosnitza[1,2], and T. Gottschall[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]TU Dresden, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung, Dresden, Germany — [4]TU Bergakademie Freiberg, Germany

The upcoming technology of magnetocaloric cooling has several advantages depending on the working temperatures. At room temperature, one can avoid environmentally harmful refrigerants and at cryogenic temperatures - for instance in hydrogen liquefaction - the process itself has a much higher Carnot efficiency than the conventional one. In both cases, a challenge is the availability of magnetocaloric materials: They usually involve large amounts of of costly rare earths to show a significant magnetocaloric effect. The ternary La(Fe,Si)$_{13}$ solves this issue, but has a transition temperature at 200 K. Recently, we showed that this transition temperature can be tuned down by introducing both Ce and Mn to the system. In this work, we show characterization results of the powder produced in sizes of 25-75 μm as characterized with electron microscopy and x-ray diffraction. In the end, we discuss the possible applicability in 3D printing techniques such as selective laser melting.

MA 51.10 Fri 12:15 H 2013

RCo2Hx magnetocaloric compounds for cryogenic gas liquefaction — •Allan Doering, Imants Dirba, Konstantin Skokov, and Oliver Gutfleisch — Technical University of Darmstadt, Darmstadt, Germany

Magnetic cooling, based on the magnetocaloric effect, is a new refrigeration technology that has been intensively developed for room temperature in recent decades. This technology could play also an important role at cryogenic temperatures to liquefy hydrogen, aiming for a future green economy and carbon-neutral societies. Typically, to use the magnetocaloric cycle, the hydrogen is pre-cooled with liquid nitrogen down to 77 K, and then magnetocaloric refrigeration is operated in the temperature range from 77 to 20 K to liquefy the H2 gas. Obviously, this new technology requires new materials. Since the maximum MCE takes place near the Curie temperature (TC), it is critical to use materials with a TC between 20 K and 77 K. The RCo2 family (where R stands for rare earth elements) are potential materials for this application due to their large MCE, however, some of these compounds have TC higher than 77 K. In our work, we tune TC of the RCo2 family to temperatures below 77 K using hydrogen as interstitial atoms. Samples were synthesized by arc-melting and annealed afterward. The quality of samples was determined by X-ray diffraction and scanning electron microscopy. Magnetization and heat capacity were measured to determine magnetocaloric effect of obtained alloys (magnetic entropy change and adiabatic temperature change. We acknowledge the HyLICAL and CRC 270 projects for the funding of this research.

MA 51.11 Fri 12:30 H 2013

Highly reversible magnetocaloric effect in $Gd_5Si_{0.25}Ge_{3.75}$ in moderate magnetic fields for hydrogen liquefaction — •Wei Liu[1], Eduard Bykov[2], Tino Gottschall[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Materials Science, Technical University of Darmstadt, Darmstadt, Germany — [2]High Magnetic Field Lab, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Magnetocaloric (MC) hydrogen liquefaction could be a 'game changer' for the liquid hydrogen industry due to its potentially higher efficiency than the conventional Joule-Thomson-expansion-based liquefaction technologies [1]. However, second-order MC materials exhibit less excellent MCEs near the nitrogen condensation point (77 K), where the hydrogen starts to be cooled by a magnetic cooling cycle to reach its condensation point (20 K) [2]. First-order MC materials can achieve much higher MCEs, but their poor reversibility due to their significant thermal hysteresis is a problem which makes their applications in real devices more complex [3]. In this work, we demonstrate that $Gd_5Si_{0.25}Ge_{3.75}$ exhibits a highly reversible MCE near 77 K in a magnetic field of 5 T despite its significant thermal hysteresis. Considering that a magnetic field of 5 T is often proposed to be used in a practical active magnetic regenerator, this work shows that first-order MC materials with significant thermal hysteresis can also be promising candidates for hydrogen liquefaction.

[1] Liu et al., J. Phys. Energy 3 (2023), 034001 [2] Liu et al., Appl. Mater. Today 29 (2022), 101624 [3] Gutfleisch et al., Phil. Trans. R. Soc. A 374 (2016), 20150308

MA 51.12 Fri 12:45 H 2013

Tuning magnetic properties in (RE,La)(Fe,Si)13 with 4f alloying — •Johanna Lill[1], Benedikt Eggert[1], Benedikt Beckmann[2], Olga N. Miroshkina[1], Konstantin Skokov[2], Jose R. Mardegan[3], Damian Günzing[1], Simon Rauls[1], Philipp Klassen[1], Tom Helbig[1], Sonia Francoual[3], Richard A. Brand[1], Kurt Kummer[4], Markus E. Gruner[1], Oliver Gutfleisch[2], Katharina J. Ollefs[1], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, UDE, Duisburg, Germany — [2]Material Science, TU Darmstadt, Darmstadt, Germany — [3]DESY, PETRA III, Hamburg, Germany — [4]ESRF, Grenoble, France

Magnetic refrigeration in comparison to gas-compression refrigerators reduces green house gas emissions drastically. Magnetocaloric (MC) materials are alloyed to 1) shift phase transition temperatures according to the need for specific applications and 2) to increase the MC effect. The size of the MC effect is proportional to the magnetic field integral of $\frac{\delta M}{\delta T}$. Therefore, the response will be stronger if the magnetic material shows a stronger magnetisation change. Here, we analyse 4f elements in the well-known material system La(Fe,Si)$_{13}$, using Ce, Nd and Pr on the La site with up to 30%. With 4f alloying, the saturation magetization strongly increases while the Fe magnetic moment, usually responsible for the overall magnetic behaviour, does not respond as detected in Mössbauer studies. We performed XMCD studies on their elements to determine the rare earths contribution to the total magnetisation. We acknowledge funding of the DFG through CRC 270 HoMMage and thank the ESRF and DESY for allocating beamtime.

MA 51.13 Fri 13:00 H 2013

Influence of hydrostatic pressure on the magnetocaloric effect of $La_{0.7}Ce_{0.3}Fe_{11.6}Si_{1.4}$ — •Benedikt Beckmann[1], Lukas Pfeuffer[1], Johanna Lill[2], Benedikt Eggert[2], David Koch[1], Barbara Lavina[3,4], Jiyong Zhao[4], Thomas Toellner[4], Esen E. Alp[4], Katharina Ollefs[2], Konstantin P. Skokov[1], Heiko Wende[2], and Oliver Gutfleisch[1] — [1]Institute of Materials Science, TU Darmstadt, Darmstadt, Germany — [2]Faculty of Physics and CENIDE, UDE, Duisburg, Germany — [3]Center for Advanced Radiation Sources, UChicago, Chicago, USA — [4]Advanced Photon Source, Argonne National Laboratory, Argonne, USA

Magnetocaloric liquefaction of hydrogen, which is a key enabler for the successful transition towards a carbon neutral society based on renewable energies, is a crucial and promising future technology. However, the current dependence on highly-critical, heavy rare-earth based magnetocaloric materials is a major disadvantage for the global usage of the technology. In this work, we aim to mitigate this limitation by using a multi-stimuli approach, utilizing isotropic pressure and magnetic field as external stimuli to tailor and induce the phase transition associated with a large caloric effect. We use non-toxic, low-cost, and low-criticality $La_{0.7}Ce_{0.3}Fe_{11.6}Si_{1.4}$, achieving phase transitions in the temperature range from 200 K down to liquid hydrogen temperatures with large isothermal entropy changes up to 28 J(kgK)$^{-1}$.

We acknowledge financial support from DFG through CRC 270 HoMMage (Project-ID 405553726) and thank the Argonne National Laboratory for allocating beamtime.

MA 52: Altermagnets

Time: Friday 9:30–13:30 Location: EB 202

MA 52.1 Fri 9:30 EB 202

Strain induced antiferromagnetic to altermagnetic transition — •Atasi Chakraborty — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Altermagnets, unconventional collinear compensated magnetic systems, offer advantages of spin polarized current akin to ferromagnets, and THz functionalities similar to antiferromagnets, while introducing new novel effects like spin-splitter currents. A key challenge for future applications and functionalization of altermagnets, is to demonstrate controlled transitioning to the altermagnetic phase from other conventional phases in a single material. Here we prove a viable path towards overcoming this challenge through a strain-induced transition from an antiferromagnetic to an altermagnetic phase in ReO2. Combining spin group symmetry analysis and ab initio calculations, we demonstrate that under compressive strain ReO2 undergoes such transition, lifting the Kramer*s degeneracy of the band structure of the antiferromagnetic phase in the non-relativistic regime. In addition, we show that this magnetic transition is accompanied by a change in the non-trivial surface state topology from one phase to the other. We calculate the distinct signature of spin polarized spectral functions of the two phases, which can be detected in angle resolved photo-emission spectroscopy experiments.

MA 52.2 Fri 9:45 EB 202

Electronic and transport properties of Rh-doped altermagnetic RuO_2 — •Lishu Zhang[1], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz,Germany

In the past years RuO_2 has emerged as a central material for understanding the basic properties of altermagnetic materials [1]. In our work, we study the effects of Rh-doping on the properties of altermagnetic RuO_2. We use first-principles methods to simulate the effect of replacing Ru atoms with Rh and study the corresponding changes in the characteristic spin-splitting with the wave vector (k) and changes in the spin-resolved Fermi surface topology. We demonstrate that the latter has a profound impact on various transport characteristics of RuO_2 [2]. We thus promote Rh-doped RuO_2 as a promising platform for tuning the electronic properties and transport effects in altermagnetic materials.

[1] Smejkal et al., Physical Review X 12(2022): 040501.
[2] Zhou et al., arXiv:2305.01410 (2023).
L.Z. is supported by the Alexander von Humboldt foundation

MA 52.3 Fri 10:00 EB 202

Growth and properties of altermagnetic RuO_2/MgO/ferromagnet tunnel junctions — •Maik Gaerner, Martin Wortmann, Laila Bondzio, Inga Ennen, Karsten Rott, Timo Kuschel, Jan Schmalhorst, and Günter Reiss — Bielefeld University, Germany

Altermagnetic materials, such as RuO_2, exhibit time-reversal symmetry breaking and non-relativistic, anisotropic spin splitting in their bandstructure. Meanwhile, they also posses zero net magnetization. Therefore, these materials are promising candidates for the use in fast and robust spinelectronic devices, such as magnetic tunnel junctions (MTJs) [1,2,3].

Here, we report on the fabrication and characterization of MTJs with one altermagnetic RuO_2 and one ferromagnetic electrode. The thin films have been grown using (reactive) magnetron sputtering. Their crystallographic structure has been investigated using specular and off-specular X-ray diffraction as well as transmission electron microscopy. Afterwards, the MTJs have been patterned by electron beam lithography. In low temperature resistivity measurements, we observe a tunneling magnetoresistance which is controlled by the orientation of the magnetization of the ferromagnetic electrode. Within this contribution, we present first experimental results and give insights into MTJs with one altermagnetic electrode.

[1] L. Šmejkal et al., Phys. Rev. X 12, 031042 (2022)
[2] B. Chi et al., arXiv:2309.09561
[3] K. Samanta et al., arXiv:2310.02139

MA 52.4 Fri 10:15 EB 202

Fragility of the magnetic order in the prototypical altermagnet RuO_2 — •Laura Garcia-Gassull[1], Andriy Smolyanyuk[2], Igor Mazin[3], and Roser Valenti[1] — [1]Goethe University, Frankfurt am Main, Germany — [2]Institute of Solid State Physics, Vienna, Austria — [3]George Mason University, Fairfax, USA

The search for a material that fulfills the requirements needed to be an altermagnet has been only increasing in recent years. A proposed material, RuO_2, has been at the center of this search. However, its magnetic properties are still controversial, with some experiments pointing towards it being an altermagnet and others a paramagnet. We present first principles electronic structure calculations that show that pristine RuO_2 is not magnetic and that altermagnetism is realized only in the presence of (Ru) vacancies. Moreover, we corroborate NMR experiments that argue for its altermagnetic nature under the effects of vacancies.

MA 52.5 Fri 10:30 EB 202

Ultrafast electron dynamics in altermagnetic KRu4O8 — •Marius Weber[1,2], Kai Leckron[1], Luca Haag[1], Rodrigo Jaeschke[2], Libor Šmejkal[2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau ,67633 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Altermagnetic materials [1] exhibit various intriguing properties, including a distinctive anisotropic band-structure landscape with an alternating spin arrangement. We present here a numerical investigation of optically-induced electronic dynamics in altermagnetic KRu4O8. Ab-initio band structure and the corresponding dipole matrix elements are used as input to determine optically excited carrier distributions from a Fermi's Golden Rule approach. To investigate the characteristics of electronic dynamics in altermagnets, it is crucial to compute the microscopic momentum-dependent scattering dynamics throughout the whole Brillouin zone. We utilize a tight-binding model and calibrate the model parameters to the DFT band structure, which captures the essential momentum-space characteristics of KRu4O8. We numerically determined the electron dynamics resulting from electron-phonon [2] and electron-electron interactions. We characterize the influence on charge and spin dynamics dynamics throughout the entire Brillouin zone, and highlight the importance Elliot-Yafet spin flips.

[1] L. Šmejkal et al.; Phys. Rev. X 12, 031042 (2022)
[2] M. Weber et. al.; arXiv:2305.00775

MA 52.6 Fri 10:45 EB 202

Strain induced anomalous Hall effect in the altermagnet ruthenium-dioxide — •Bennet Karetta[1], V.K. Bharadwaj[1], R. Jaeschke-Ubiergo[1], Libor Šmejkal[1,2], and Jairo Sinova[1,3] — [1]Insitut fur Physik, Johannes Gutenberg Universität Mainz, D-55099 — [2]Inst. of Physics Academy of Sciences of the Czech Republic, Cukrovarnicka 10, Praha 6, Czech Republic — [3]Department of Physics, Texas A\&M University, College Station, Texas 77843-4242, USA

We explore the influence of strain on the magnetic and anomalous Hall transport properties of altermagnetic RuO2. We illustrate a shift from an out-of-plane to an in-plane magnetic moment configuration under a sufficient shear strain. This strain-induced symmetry breaking presents in RuO2, resulting in a measurable anomalous Hall effect response. This effect involves a two-step switch in the Hall conductivity. For minor strains, the out-of-plane component of the Hall vector becomes non-zero. After reorientation of magnetic moments, an inplane component can be generated. We demonstrate that the Berry's curvature-mediated anomalous Hall effect exhibits a substantial magnitude, on the order of hundreds of S/cm. The non-zero components undergo a change when the Néel order reorients from out-of-plane to in-plane. Our findings point towards possible application of strain-controlled magneto-transport based devices based on light common elements, paving the way to sustainable environmentally friendly sensory systems.

MA 52.7 Fri 11:00 EB 202

Anomalous Nernst effect in the altermagnet Mn5Si3 — •Warlley Hudson Campos[1], Venkata Krishna Bharadwaj[1], Rodrigo Jaeschke-Ubiergo[1], Antonin Bad'ura[2], Helena Reichlova[2], Libor Šmejkal[1,2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany — [2]Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

Altermagnets (AMs), a recently discovered class of magnetic materials, exhibit compensated magnetic ordering and alternating spin-polarization in both direct and reciprocal spaces [1]. AM belong to a different symmetry class from ferromagnets (FMs) and antiferromagnets (AFs) and can host unique properties (spin splitter currents) as well as combine properties of ferromagnets (spin polarized currents) and antiferromagnets (ultrafast spin dynamics). Here, we employ symmetry analysis and first-principle calculations to investigate the anomalous Nernst effect (ANE), the transverse electric response to an applied longitudinal temperature gradient, in the AM phase of Mn5Si3 [2]. We investigate the dependence of the ANE tensor with respect to the orientation of the spin quantization axes. In our calculations, we also demonstrate the controllability of Nernst conductivity through manipulation of chemical potential and temperature. Finally, we discuss possible experimental geometries for observation of ANE.

[1] L. Šmejkal, et al., Phys. Rev. X 12, 031042 (2022). [2] I. Kounta, et al., Phys. Rev. Mat. 7, 024416 (2023).

MA 52.8 Fri 11:15 EB 202

Magnetooptical effects in altermagnet MnTe — •Venkata Krishna Bharadwaj[1], Warlley Hudson Campos[1], Rodrigo Jaeschke-Ubiergo[1], Libor Šmeijkal[1,2], and Jairo Sinova[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, D-55099 Mainz, Germany — [2]Inst. of Physics Academy of Sciences of the Czech Republic, Cukrovarnická 10, Praha 6, Czech Republic

A recent breakthrough in the field of magnetism unveiled a novel category of magnetic materials known as altermagnets [1]. Altermagnets represent a unique class of magnetic compounds characterized by magnetic compensation, breaking time-reversal symmetry and resulting in a spin-split band structure. This band structure exhibits alternating spin polarization both in real and reciprocal spaces. The underlying origin of this spin splitting can be traced to variations in local crystal field anisotropies across different magnetic sublattices.

In this study, we explore the magneto-optical response in altermagnets using first principles. Specifically, we focus on MnTe, which is predicted to bean altermagnetic insulator [1] where the altermagnetism can be examined through the magneto-optical Kerr effect. Our findings provide a foundation for exploring optical responses in other altermagnetic materials.

[1] L. Šmejkal, et al., Phys. Rev. X 12, 031042 (2022).

15 min. break

MA 52.9 Fri 11:45 EB 202

Mechanisms for stabilizing altermagnetism in minimal models — Mercè Roig[1], •Andreas Kreisel[1], Brian M. Andersen[1], Yue Yu[2], and Daniel F. Agterberg[2] — [1]Niels Bohr Institute, University of Copenhagen, DK-2200 Copenhagen, Denmark — [2]Department of Physics, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201, USA

Altermagnetism has been proposed as a new magnetic phase that shares properties of antiferromagnets and ferromagnets like no net magnetization but finite anomalous Hall effect. In this work, we use minimal models to study the 2D and 3D mechanisms giving rise to altermagnetism by examining the altermagnetic susceptibility and comparing it to the usual spin susceptibility. In particular, in the 2D case we study the interplay between interband and intraband susceptibility and the effect of Van Hove singularities to stabilize altermagnetism. Finally, we discuss relevant tight-binding models for altermagnetic materials candidates, including the rutile metal RuO_2. We demonstrate that the minimal tight-binding models are sufficient to capture a leading altermagnetic instability.

MA 52.10 Fri 12:00 EB 202

Anomalous Nernst effect of altermagnetic Mn_5Si_3 — •Antonin Badura[1], Warlley Campos[2], Javier Rial[3], Ismaïla Kounta[4], Lisa Michez[4], Jan Zemen[5], Filip Křížek[1], Kamil Olejník[1], Dominik Kriegner[1], Sebastian Sailer[6], Jairo Sinova[2], Vincent Baltz[3], Tomas Jungwirth[1], Libor Šmejkal[2], Sebastian T. B. Goennenwein[6], and Helena Reichlova[1] — [1]Institute of Physics, Czech Academy of Sciences, Prague, Czechia — [2]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [3]Univ. Grenoble Alpes, CNRS, CEA, Grenoble INP, Spintec, Grenoble, France — [4]Aix-Marseille University, CNRS, CINaM, Marseille, France — [5]Faculty of Electrical Engineering, Czech Technical University in Prague, Czechia — [6]Universität Konstanz, Fachbereich Physik, Konstanz, Germany

The spin-split electronic band structure of altermagnetic materials gives rise to various spintronic phenomena, many of which were already confirmed experimentally. However, an experimental investigation of thermoelectric phenomena in altermagnets, such as the anomalous Nernst effect, is still missing. Here, we demonstrate the presence of the anomalous Nernst effect in a particular altermagnetic candidate, thin epitaxial layers of Mn_5Si_3. The transverse Nernst voltage is generated by a temperature gradient in the sample (0001) plane. We carefully analyze the dependence of the Nernst signal on the applied magnetic field and identify multiple contributions to the signal, demonstrating the complex transport response of our layers. Furthermore, our experimental study is supported by *ab initio* calculations of the anomalous Nernst coefficient in Mn_5Si_3.

MA 52.11 Fri 12:15 EB 202

Impacts of Crystallographic Domain Boundaries on the Electronic Properties of RuO2 — •Gina Pantano[1], Eklavya Thareja[1], Libor Šmejkal[2,3], Jairo Sinova[2], and Jacob Gayles[1] — [1]Department of Physics, University of South Florida, Tampa, FL USA — [2]Institut für Physik, Johannes Gutenberg Universität Mainz, Mainz, Germany — [3]Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic

Research on interfacial phenomena in condensed matter physics has garnered significant interest due to the discovery of new properties and phases distinct from the bulk. Our work investigates novel effects that arise from crystallographic domain boundaries in the altermagnet ruthenium dioxide (RuO2). Altermagnets are characterized by having a non-relativistic momentum-dependent spin splitting comparable to ferromagnetic materials but with compensated magnetic ordering. This offers a new mechanism for controlling spin-dependent transport phenomena, such as the spin and anomalous Hall effects, based on the configuration of the crystal. We use first principle calculations to determine the orbital, atomic, and spin contributions to the electronic states at the interface. We expect the emergence of a transverse voltage parallel to the interface without spin-orbital coupling due to spin scattering and novel spin currents to develop when spin-orbit coupling is considered. Our findings will further our understanding of how altermagnetic properties evolve toward interfaces with the reduction in dimensionality and symmetry and contribute to advancements toward the design of sustainable, energy-efficient low-power devices.

MA 52.12 Fri 12:30 EB 202

Altermagnetic band splitting in CrSb thin films investigated by photoemission spectroscopy — •Lukas Odenbreit[1], Sonka Reimers[1], Libor Smejkal[1], Vladimir Strocov[2], Procopios Constantinou[2], Anna Hellenes[1], Rodrigo Jaeschke Ubiergo[1], Warlley Campos[1], Venkata Bharadwaj[1], Atasi Chakraborty[1], Mathias Kläui[1], Jairo Sinova[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099Mainz, Germany — [2]Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

Altermagnets are characterized by a collinear magnetic phase with compensated order in real space and alternating spin polarization in reciprocal space.

Using spin-integrated soft X-ray angular resolved photoemission spectroscopy (SX-ARPES), we observe directly the associated band splitting near the Fermi energy. The SX-ARPES data obtained from epitaxial thin films of the anticipated antiferromagnetic material CrSb enable a comprehensive comparison with band structure calculations. Our analysis reveals a robust agreement between the experimental results and the theoretical predictions, thereby providing strong evidence for the characterization of CrSb as an altermagnet [Rei23].

The observed maximum altermagnetic band splitting of approximately 0.6 eV in proximity to the Fermi energy underscores the promising potential of altermagnets in advancing applications within the realm of spintronics.

[Rei23] S. Reimers et al., arXiv:2310.17280v1 (2023).

MA 52.13 Fri 12:45 EB 202

Inverse Faraday Effect in altermagnets from first-principles — •Theodoros Adamantopoulos[1,2], Maximilian Merte[1,2,3], Frank Freimuth[1,3], Dongwook Go[1,3], Stefan Blügel[1], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

While the understanding of altermagnetism is still at a very early stage, it is expected to play a role in various fields of condensed matter research, for example spintronics, caloritronics and superconductivity [1]. In the field of optical magnetism, it is still unclear whether altermagnets can exhibit magnetisation dynamics effects distinct from ferromagnets and antiferromagnets. Here we choose RuO_2, a prototype metallic altermagnet with a giant spin splitting, and CoF_2, an experimentally known insulating altermagnet, to study the inverse Faraday effect (IFE) in altermagnets from first-principles. We predict large and canted induced spin and orbital moments after the optical excitation which are distinct on each magnetic sublattice. By resorting to microscopic tools we interpret our results in terms of the altermagnetic spin splittings and of their reciprocal space distribution. Overall, in accordance with our symmetry analysis, we demonstrate that the behavior of altermagnets when exposed to optical pulses incorporates both ferromagnetic and antiferromagnetic features.

[1] L. Smejkal et al. PRX**12**, 040501 (2022).

MA 52.14 Fri 13:00 EB 202

Altermagnetic signatures in the ultrafast photoconductivity of RuO2 — •Stephan Wust[1], Marius Weber[1], Akashdeep Akashdeep[2], Luca Haag[1], Kai Leckron[1], Christin Schmitt[2], Rafael Ramos[3], Takashi Kikkawa[4], Eiji Saitoh[4], Mathias Kläui[2], Libor Šmejkal[2], Jairo Sinova[2], Martin Aeschlimann[1], Gerhard Jakob[2], Hans Christian Schneider[1], and Benjamin Stadtmüller[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [3]CIQUS, Departamento de Química-Física, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [4]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan

The discovery of altermagnets as a new class of magnets opens new avenues to exploit spin-polarized electron conductivity in materials with compensated spin structures. This is possible due to the spin-split band structure of altermagnets and the corresponding non-relativistic spin polarization, leading to novel effects such as spin-splitter currents. Here, we demonstrate the existence of characteristic altermagnetic signatures in the photoconductivity of the prototypical altermagnet RuO2 after optical excitation using fs light pulses. This is achieved by combining all-optical pump-probe methods with ab-initio calculations, which together provide insight into the spin polarization of the optically excited carriers in RuO2 for different excitation geometries.

MA 52.15 Fri 13:15 EB 202

Zero-Field Crystal Thermal Hall Effect in Insulating Altermagnets — •Rhea Hoyer, Libor Šmejkal, and Alexander Mook — Johannes Gutenberg Universität Mainz, Mainz, Deutschland

The thermal Hall effect is an emerging probe of charge-neutral collective excitations in insulating quantum matter. Here we address the question of whether thermal Hall effects can occur in compensated collinear magnets at zero magnetic field. Following the recently developed concept of altermagnetism [1,2,3], we provide an affirmative answer by developing a minimal model that exhibits a crystal thermal Hall effect. Specifically, we present a Heisenberg-type spin model on the rutile lattice. The presence of nonmagnetic atoms causes altermagnetic spin-splitting of magnons [4,5] and gives rise to Dzyaloshinskii-Moriya interaction. As microscopic heat carriers, we consider magnons, whose Berry curvature causes an intrinsic contribution to the thermal Hall conductivity [6]. We show how the Hall conductivity changes as a function of the Néel vector direction, highlighting the influence of magnetic point group symmetries. The role of symmetry is further emphasized by studying fluctuation induced piezomagnetism and strain engineering of the Hall conductivity. Finally, the thermal Hall response is contrasted with a spin-Nernst response to explore the potential for heat-to-spin conversion in altermagnetic insulators.

[1] L.Š. et al., PRX 12, 031042 (2022). [2] L.Š. et al., PRX 12, 040501 (2022). [3] L.Š. et al., Sci. Adv.6, eaaz8809 (2020). [4] L.Š. et al., arXiv:2211.13806 (PRL, accepted). [5] M.G. et al., PRL 126, 127701 (2023). [6] R.M. et al., PRL 106, 197202 (2011).

MA 53: Skyrmions IV

Time: Friday 9:30–10:45 Location: EB 301

MA 53.1 Fri 9:30 EB 301

Putative formation of an antiferromagnetic Skyrmion lattice in J_2-frustrated spinel compounds $MnSc_2X_4$ (X=S, Se) — •Justus Grumbach[1], Mahmoud Deeb[1], Andreas Hauspurg[1,2], Sergey Granovsky[1], Sergei Zherlitsin[2], and Mathias Doerr[1] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01069 Dresden, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Spinels are a superposition of a pyrochlor and a diamond substructure. In the case of $MnSc_2X_4$ the magnetic Mn^{3+}-ions form the diamond substructure with a dominant second nearest neighbour-exchange (J_2>J_1), which leeds to magnetic frustration. New magnetic phase diagrams could be deduced by magnetoelastic measurements for both compounds. For $MnSc_2S_4$ in H||[111] an antiferromagnetic skyrmion-lattice could be found in a broad region between 5T and 8T, up to 2K, confirming former INS-measurements and simulations. Furthermore, the skyrmionic phase could be reproduced by a new simulation based on thermodynamics, connected to the experiments. Otherwise, measurements of $MnSc_2Se_4$ as well as the resulting phase diagram clearly show no hints for a skyrmionic phase.

A comparison of dilatometry measurements and resulting phase diagrams with special consideration of the skyrmion-lattice will be the main message of the talk.

MA 53.2 Fri 9:45 EB 301

Skyrmion Ordering in Geometric Confinements — •Raphael Gruber, Jan Rothörl, Simon Fröhlich, Fabian Kammerbauer, Elizabeth Martín Jefremovas, Peter Virnau, and Mathias Kläui — Institut für Physik, Johannes-Gutenberg Universität Mainz, 55099 Mainz, Germany

Magnetic skyrmions are chiral, quasi-particle spin textures that are considered as promising candidates for data storage, logic and non-conventional computing devices [1]. Furthermore, dense arrangements of skyrmions in thin films allow us to observe 2D phase behavior [2], which significantly differs from 3D systems. In confined geometries, we identify how the patterned structures significantly impact the ordering behavior of the skyrmions. We analyze the characteristic lattice behavior in our system and show how random diffusion and the pinning landscape [3] contribute to the features and capabilities of our system in the context of phase observations and the design of nanodevices.

[1] Zázvorka et al., Nat. Nanotechnol. 14, 658-661 (2019) [2] Zázvorka et al., Adv. Funct. Mater. 30, 2004037 (2020). [3] Gruber et al., Nat. Commun. 13, 3144 (2022).

MA 53.3 Fri 10:00 EB 301

Helical to conical order in M1/3 NbS2 (M=Cr, Mn), detected by Cr, Mn NMR — •Manaswini Sahoo[1,2], Pietro Bonafa[2], Amelia Hall[3], Daniel Mayoh[3], Laura Corredor[1], Bernd Buechner[1], Geetha Balakrishnan[3], Roberto De Renzi[2], and Giuseppe Allodi[2] — [1]Leibniz IFW Dresden,Germany — [2]University of Parma,Italy — [3]Department of Physics, University of Warwick, United Kingdom

Recently, the materials Cr1/3NbS2 have piqued the interest of researchers as rare examples of 2D materials with helical magnetic ordering, thought to occur due to competition between exchange and DMI. When a magnetic field is applied perpendicular to the c-axis, the helical ground state transforms into the chiral soliton lattice (CSL). A chiral conical phase (CCP) emerges when the magnetic field is applied along the c-axis. Both phases are well established in Cr3/NbS2. However, the other member of the family, Mn1/3NbS2 has a similar crystal structure but complex magnetic behavior. Cr single-crystal NMR measurements demonstrate the first-order nature of the helical-to-paramagnetic phase transition and determine the exact boundaries of the conical phase. Similarities with Mn single crystal NMR results are discussed.

MA 53.4 Fri 10:15 EB 301

Current induced nucleation of spin textures in aperiodic multilayers — Riccardo Battistelli[1,2], Kai Litzius[2], Matthieu Grelier[3], •Krishnanjana Puzhekadavil Joy[1,2], Michael Schneider[4], Christian M Günther[5], Kathinka Gerlinger[4], Christopher Klose[4], Daniel Metternich[1,2], Lisa Marie Kern[4], Manas Ranjan Patra[1,2], Tamer Karaman[1,2], Josefin Fuchs[4], Sascha Petz[1], Stefan Eisebitt[4,5], Bastian Pfau[4], Nicolas Reyren[3,6], Vincent Cros[3], and Felix Büttner[1,2] — [1]Helmholtz Zentrum Berlin, Germany — [2]University of Augsburg, Germany — [3]Unité Mixte de Physique, CNRS-Thales, Palaiseau, France. — [4]Max Born Institute,Berlin,Germany — [5]Technische Universität Berlin, Germany — [6]SOLEIL Synchrotron, Gif-sur-Yvette Cedex, France

Magnetic cocoons are ellipsoid-shaped 3D structures, that have been recently observed in aperiodic multilayers where magnetic interactions are varied along the thickness. Here we report the feasibility of the production of these cocoons using nanosecond current pulses in Pt/Co/Al aperiodic multilayer system. The images obtained using Scanning Transmission X-ray Microscopy also show other complex spin textures when stronger pulses are applied. Simulations show that these current pulses heat up the system. It also creates an Oersted field in addition to the applied magnetic field.The magnetic field-temperature phase diagram can be thus obtained from such images. The measurements lead to the conclusion that the magnetic field and temperature aid the system to a fluctuation state where the cocoons are nucleated.

MA 53.5 Fri 10:30 EB 301

Topological spin textures in nominally centrosymmetric van der Waals magnet — •Rana Saha, Holger Meyerheim, and Stuart Parkin — Max Planck Institute of Microstructure Physics, Halle (Saale), Germany

Current spintronics research explores magnetic materials with adjacent non-collinear magnetic moments, giving rise to intricate topological spin textures, notably skyrmions. These nano-objects feature chiral magnetic boundaries and circular shapes, traditionally requiring non-centrosymmetric crystal structures and Dzyaloshinskii-Moriya exchange interactions for their formation. Recently skyrmions have been observed in several centrosymmetric materials [1]. Here we show evidence for skyrmions in CrTe2, a member of the van der Waals (vdW) materials family, which is nominally centrosymmetric. The presence of Cr self-intercalation into vdW gaps, coupled with the development of a three-dimensional long-range ordered superstructure, alters the space group symmetry from centrosymmetric to the acentric. This transformation results from the uneven occupancy of Cr atoms in the two vdW gaps per unit cell, creating an asymmetric environment. Notably, Néel-type skyrmions are directly observed using in-situ Lorentz transmission electron microscopy across a broad temperature range and magnetic fields [2]. This study highlights that self-intercalation in vdW materials offers a novel avenue for generating synthetic skyrmions.

References [1] A. Chakraborty, et al., Adv. Mater. 34 (2022) 2108637. [2] R. Saha, et al., Nat. Commun. 13 (2022) 3965.