Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

(Lecture halls H16, H17, H18, H19, H20, and H36; Poster P1 and P3)

Invited Talks

MA 5.1	Mon	9:30–10:00	H20	**Driving Coherent Phonon-Phonon Angular Momentum Transfer via Lattice Anharmonicity** — •Sebastian Maehrlein
MA 5.2	Mon	10:00–10:30	H20	**Chiral phonons, phono-magnetism, and spin-rotation coupling** — •Matthias Geilhufe
MA 5.3	Mon	10:30–11:00	H20	**Geometry of temporal chiral structures and photoinduced chirality-spin coupling** — •Olga Smirnova, Philip Flores, Aycke Roos, David Ayuso, Piero Decleva, Stefanos Carlstroem, Serguei Patchkovskii, Andres Ordonez
MA 5.4	Mon	11:15–11:45	H20	**Phonon thermal Hall effect** — •Kamran Behnia
MA 5.5	Mon	11:45–12:15	H20	**Giant effective magnetic moment of chiral phonons** — •Swati Chaudhary, Dominik Juraschek, Martin Rodriguez-Vega, Gregory A Fiete
MA 6.1	Mon	15:00–15:30	H16	**Magnetization dynamics of chiral helimagnetic insulators** — •Aisha Aqeel
MA 7.1	Mon	15:00–15:20	H18	**Realizing Reservoir Computing with skyrmions in geometrical confinements tuned by ion irradiation** — •Grischa Beneke
MA 7.2	Mon	15:20–15:40	H18	**Low-energy spin excitations of the Kitaev candidate material $Na_2Co_2TeO_6$ probed by high-field/high-frequency electron spin resonance spectroscopy** — •Luca Bischof, Jan Arneth, Kwang-Yong Choi, Raju Kalaivanan, Raman Sankar, Rüdiger Klingeler
MA 7.3	Mon	15:40–16:00	H18	**Tailoring the first-order magnetostructural phase transition in Ni-Mn-Sn for caloric applications by microstructure** — •Johannes Puy, Enrico Bruder, Oliver Gutfleisch, Franziska Scheibel
MA 7.4	Mon	16:15–16:40	H18	**Tuning the properties of two-dimensional magnetic heterostructures via interface engineering with molecular and inorganic van der Waals crystals.** — •Carla Boix-Constant, Samuel Mañas-Valero, Eugenio Coronado
MA 7.5	Mon	16:40–17:05	H18	**Theoretical Prediction for Probing Magnon Topology** — •Robin R. Neumann
MA 7.6	Mon	17:05–17:30	H18	**Multiphysics-Multiscale Simulation of Additively Manufactured Functional Materials** — •Yangyiwei Yang
MA 23.1	Wed	9:30–10:00	H20	**Magneto-transport effects in crystalline magnetic films** — •Sebastian T. B. Goennenwein
MA 23.2	Wed	10:00–10:30	H20	**Cubic magneto-optic Kerr effect in thin films depending on structural domain twinning and crystal orientation** — •Robin Silber, Maik Gaerner, Jaroslav Hamrle, Timo Kuschel
MA 23.5	Wed	11:15–11:45	H20	**electrical and optical detection of the multipolar structure in the magnetization space** — •Dazhi Hou
MA 23.9	Wed	12:30–13:00	H20	**Ultrafast Néel order dynamics detected by time-resolved magneto-optical Voigt effect** — •Haibin Zhao
MA 30.1	Wed	16:00–16:30	H18	**Boosting Coercivity in Additively Manufactured Magnets Through Nano-Functionalization of NdFeB Powder** — •Anna Ziefuss
MA 35.1	Thu	9:35–10:05	H20	**Artificial Intelligence for Materials Science: Critical Importance of Rare Events, Active Learning, and Uncertainties** — •Matthias Scheffler

MA 35.2	Thu	10:05–10:35	H20	**Physics meets data: decoding magnetic inhomogeneities through latent analysis** — •Karin Everschor-Sitte
MA 35.3	Thu	10:35–11:05	H20	**AI used for micromagnetic simulations** — •Thomas Schrefl, Felix Lasthofer, Qais Ali, Heisam Moustafa, Harald Oezelt, Alexander Kovacs, Masao Yano, Noritsugu Sakuma, Akihito Kinoshita, Tetsuya Shoji, Akira Kato
MA 35.4	Thu	11:15–11:45	H20	**Future method for estimating parameters in magnetic films using machine learning** — •Kenji Tanabe
MA 38.1	Thu	15:00–15:30	H18	**Liquid-mediated surface-surface interactions investigated by close-to-surface magnetic particle transport** — •Rico Huhnstock, Yahya Shubbak, Arno Ehresmann
MA 39.1	Thu	15:00–15:30	H19	**Voltage control of magnetism using hydrogen** — •Markus Gößler

Invited Talks of the joint SKM Dissertationspreis 2025 (SYSD)

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	9:30–10:00	H2	**Nanoscale Chemical Analysis of Ferroic Materials and Phenomena** — •Kasper Aas Hunnestad
SYSD 1.2	Mon	10:00–10:30	H2	**Advanced Excitation Schemes for Semiconductor Quantum Dots** — •Yusuf Karli
SYSD 1.3	Mon	10:30–11:00	H2	**Aspects and Probes of Strongly Correlated Electrons in Two-Dimensional Semiconductors** — •Clemens Kuhlenkamp
SYSD 1.4	Mon	11:00–11:30	H2	**Mean back relaxation and mechanical fingerprints: simplifying the study of active intracellular mechanics** — •Till Münker
SYSD 1.5	Mon	11:30–12:00	H2	**Coherent Dynamics of Atomic Spins on a Surface** — •Lukas Veldman

Invited Talks of the joint Symposium AI-driven Materials Design: Recent Developments, Challenges and Perspectives (SYMD)

See SYMD for the full program of the symposium.

SYMD 1.1	Mon	15:00–15:30	H1	**Learning physically constrained microscopic interaction models of functional materials** — •Boris Kozinsky
SYMD 1.2	Mon	15:30–16:00	H1	**GRACE universal interatomic potential for materials discovery and design** — •Ralf Drautz
SYMD 1.3	Mon	16:00–16:30	H1	**Multiscale Modelling & Machine Learning Algorithms for Catalyst Materials: Insights from the Oxygen Evolution Reaction** — •Nong Artrith
SYMD 1.4	Mon	16:45–17:15	H1	**Inverse Design of Materials** — •Hongbin Zhang
SYMD 1.5	Mon	17:15–17:45	H1	**Data-Driven Materials Science** — •Miguel Marques

Invited Talks of the joint Symposium Pushing the Boundaries of Fair Data Practices for Condensed Matter Insights: From Workflows to Machine Learning (SYFD)

See SYFD for the full program of the symposium.

SYFD 1.1	Wed	9:30–10:00	H1	**Pushing the Boundaries of Fair Data Practices for Condensed Matter Insight** — •Astrid Schneidwind
SYFD 1.2	Wed	10:00–10:30	H1	**Establishing Workflows of Experimental Solar Cell Data into NOMAD** — Edgar Nandayapa, Paolo Graniero, Jose Marquez, Michael Götte, •Eva Unger
SYFD 1.3	Wed	10:30–11:00	H1	**Building up the EOSC Federation** — •Ute Gunsenheimer
SYFD 1.4	Wed	11:15–11:45	H1	**Data-Driven Materials Science for Energy-Sustainable Applications** — •Jacqueline Cole
SYFD 1.5	Wed	11:45–12:15	H1	**Machine Learning and FAIR Data in X-ray Surface Science** — •Stefan Kowarik

Invited Talks of the joint Symposium Spins in Molecular Systems: Strategies and Effects of

Hyperpolarization (SYMS)

See SYMS for the full program of the symposium.

SYMS 1.1	Wed	15:00–15:30	H1	**Exploring the Non-Perturbative Magnetic Resonance Drive Regime with spin selection rules in a π-Conjugated Polymer** — •Christoph Boehme
SYMS 1.2	Wed	15:30–16:00	H1	**The puzzle of spin and charge transport in the chirality induced spin selectivity effect** — •Bart van Wees
SYMS 1.3	Wed	16:00–16:30	H1	**Nano- and Microscale NMR spectroscopy with spin qubits in diamond** — •Nabeel Aslam
SYMS 1.4	Wed	16:45–17:15	H1	**Spin effects in adsorbed organometallic complexes** — •Richard Berndt
SYMS 1.5	Wed	17:15–17:45	H1	**Quantum Computing with Molecules** — •Mario Ruben

Invited Talks of the joint Symposium Electronic Structure Theory for Quantum Technology: From Complex Magnetism to Topological Superconductors and Spintronics (SYES)

See SYES for the full program of the symposium.

SYES 1.1	Fri	9:30–10:00	H1	**Ab-initio Design of superconductors** — •Lilia Boeri
SYES 1.2	Fri	10:00–10:30	H1	**Topological superconductivity from first principles** — Bendegúz Nyári, András Lászlóffy, Levente Rózsa, Gábor Csire, Balázs Újfalussy, •László Szunyogh
SYES 1.3	Fri	10:30–11:00	H1	**First-principles study and mesoscopic modeling of two-dimensional spin and orbital fluctuations in FeSe** — •Myrta Grüning, Abyay Ghosh, Piotr Chudzinski
SYES 1.4	Fri	11:15–11:45	H1	**Non-collinear magnetism in 2D materials from first principles: Multiferroic order and magnetoelectric effects.** — •Thomas Olsen
SYES 1.5	Fri	11:45–12:15	H1	**Spin-phonon and magnon-phonon interactions from first principles** — •Marco Bernardi

Sessions

MA 1.1–1.3	Sun	16:00–18:15	H4	**Into the Third (and Fourth) Dimension: Imaging Methods for 3D Nanomagnetism (joint session MA/TUT)**
MA 2.1–2.10	Mon	9:30–12:15	H16	**Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)**
MA 3.1–3.13	Mon	9:30–13:00	H18	**Magnonics I**
MA 4.1–4.9	Mon	9:30–11:45	H19	**Electron Theory of Magnetism and Correlations**
MA 5.1–5.8	Mon	9:30–13:00	H20	**Focus Session: Magnetic Phenomena from Phonon Chirality and Angular Momentum I (joint session MA/TT)**
MA 6.1–6.12	Mon	15:00–18:30	H16	**Skyrmions I**
MA 7.1–7.6	Mon	15:00–18:00	H18	**INNOMAG e.V. Prizes 2025 (Diplom-/Master and Ph.D. Thesis)**
MA 8.1–8.9	Mon	15:00–17:15	H19	**Spin-Dependent Phenomena in 2D (joint session MA/HL)**
MA 9.1–9.13	Mon	15:00–18:30	H20	**Altermagnets I**
MA 10.1–10.12	Tue	9:30–12:45	H16	**Focus Session: Magnetic Phenomena from Phonon Chirality and Angular Momentum II (joint session MA/TT)**
MA 11.1–11.14	Tue	9:30–13:15	H18	**Spin Transport and Orbitronics, Spin-Hall Effects I (joint session MA/TT)**
MA 12.1–12.8	Tue	9:30–11:30	H19	**Magnetization Dynamics and Damping**
MA 13.1–13.13	Tue	9:30–13:00	H20	**Altermagnets II**
MA 14.1–14.9	Tue	9:30–13:15	H36	**Focus Session: Strongly Correlated Quantum States in Moire Heterostructures (joint session TT/HL/MA)**
MA 15.1–15.48	Tue	10:00–12:30	P1	**Poster I**
MA 16.1–16.5	Tue	14:00–15:15	H16	**Topological Insulators (joint session MA/HL)**
MA 17.1–17.4	Tue	14:00–15:00	H18	**Micro- and Nanostructured Magnetic Materials**
MA 18.1–18.6	Tue	14:00–15:30	H19	**Functional Antiferromagnetism**
MA 19.1–19.5	Tue	14:00–15:15	H20	**Magnetic Imaging and Sensors**
MA 20.1–20.14	Wed	9:30–13:15	H16	**Magnonics II**
MA 21.1–21.12	Wed	9:30–12:45	H18	**Frustrated Magnets I**
MA 22.1–22.8	Wed	9:30–11:30	H19	**Caloric Effects in Ferromagnetic Materials**

MA 23.1–23.9	Wed	9:30–13:00	H20	**Focus Session: Magneto-Transport and Magneto-Optics of Higher Orders in Magnetization I**
MA 24.1–24.7	Wed	9:30–12:45	H36	**Focus Session: Nonlinear Spectroscopy of Collective Excitations in Quantum Magnets (joint session TT/MA)**
MA 25.1–25.2	Wed	15:00–15:30	H15	**Focus Session: Physics of the van der Waals Magnetic Semiconductor CrSBr I (joint session HL/MA)**
MA 26.1–26.14	Wed	15:00–18:45	H16	**Ultrafast Magnetization Effects I**
MA 27.1–27.3	Wed	15:00–15:45	H18	**Focus Session: Magneto-Transport and Magneto-Optics of Higher Orders in Magnetization II**
MA 28.1–28.9	Wed	15:00–17:30	H19	**Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions**
MA 29.1–29.14	Wed	15:00–18:45	H20	**Skyrmions II**
MA 30.1–30.7	Wed	16:00–18:00	H18	**Bulk Materials: Soft and Hard Permanent Magnets**
MA 31.1–31.47	Wed	17:00–19:30	P1	**Poster II**
MA 32.1–32.6	Wed	17:30–19:00	H19	**Spin Transport and Orbitronics, Spin-Hall Effects II (joint session MA/TT)**
MA 33.1–33.13	Thu	9:30–13:00	H16	**Non-Skyrmonic Magnetic Textures I**
MA 34.1–34.12	Thu	9:30–12:45	H18	**Molecular Magnetism**
MA 35.1–35.5	Thu	9:30–13:00	H20	**PhD Focus Session: Using Artificial Intelligence Tools in Magnetism**
MA 36.1–36.7	Thu	9:30–12:45	H36	**Focus Session: Ising Superconductivity in Monolayer Transition Metal Dichalcogenides (joint session TT/HL/MA)**
MA 37.1–37.10	Thu	15:00–17:45	H16	**Magnetic Imaging Techniques**
MA 38.1–38.10	Thu	15:00–18:00	H18	**Magnetic Particles / Clusters & Biomagnetism**
MA 39.1–39.7	Thu	15:00–17:00	H19	**Magnetic Thin Films**
MA 40.1–40.10	Thu	15:00–17:45	H20	**Frustrated Magnets II**
MA 41.1–41.47	Thu	15:00–17:30	P3	**Poster III**
MA 42	Thu	18:00–19:00	H20	**Members' Assembly**
MA 43.1–43.14	Fri	9:30–13:15	H16	**Skyrmions III / Non-Skyrmionic Magnetic Textures II**
MA 44.1–44.8	Fri	9:30–13:00	H17	**Focus Session: Physics of the van der Waals Magnetic Semiconductor CrSBr II (joint session HL/MA)**
MA 45.1–45.11	Fri	9:30–12:30	H18	**Computational Magnetism**
MA 46.1–46.11	Fri	9:30–12:30	H19	**Surface Magnetism**
MA 47.1–47.6	Fri	9:30–11:00	H20	**Altermagnets III**
MA 48.1–48.7	Fri	11:15–13:00	H20	**Ultrafast Magnetization Effects II**

Members' Assembly of the Magnetism Division

Thursday 18:00–19:00 H20

- Bericht
- Verschiedenes

MA 1: Into the Third (and Fourth) Dimension: Imaging Methods for 3D Nanomagnetism (joint session MA/TUT)

Nanostructured magnetic materials have found several applications in everyday objects, such as data storage devices, sensors, and biomedical devices. When one brings these materials to the third dimension, a variety of new physics, and opportunities for applications appear. However, until recently, the vast majority of experimental investigations have primarily been focused on 2D planar geometries, as 3D systems provide a set of experimental challenges that still needs to be overcome. This tutorial seeks to provide a comprehensive overview for both experts and non-experts in the field of 3D imaging to gain a deeper understanding of the recent advances and experimental challenges connected to the investigation of 3D magnetic systems.

Organized by Claire Donnelly (MPI-CPFS, Dresden, Germany) and Simone Finizio (Paul Scherrer Institut, Villigen, Switzerland).

Time: Sunday 16:00–18:15 Location: H4

Tutorial MA 1.1 Sun 16:00 H4

3D Magnetic Imaging: Utilizing Synchrotron X-Ray Coherence for Nanometric Resolution in Thick Samples — •Marisel Di Pietro Martinez — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — International Institute for Sustainability with Knotted Chiral Meta Matter (WPI-SKCM2)

In recent years, there has been a growing interest from the magnetism community in expanding to three-dimensional magnetic systems - from exploring new geometries to revealing complex magnetic textures arising in micrometer-thick samples. A key aspect of this exploration is the ability to visualize the magnetization vector field at the nanoscale throughout the entire sample, made possible by the development of 3D magnetic imaging. This technique can achieve nanometric spatial resolution in micrometer-thick samples by leveraging the penetration depth and coherence of synchrotron X-rays. Furthermore, the coherence of the X-ray beam provides magnetic contrast not only in the absorption of the transmitted wave, but also in the phase. This phase contrast enables the investigation of micron-sizes magnets, even with soft X-rays, while minimizing the sample damage. In this tutorial, I will introduce how to exploit these advantages using coherence-based techniques, such as Fourier transform holography and ptychography, to perform 3D magnetic imaging. Visualizing the magnetization vector field with nanometer spatial resolution in micrometer thick samples opens the door to studying magnetic textures in higher dimensions, offering insights into fundamental physical phenomena as well as promising new applications in information storage and processing.

Tutorial MA 1.2 Sun 16:45 H4

Nanoscale Mapping of Magnetic Textures in 3D Using Vector Field Electron Tomography — •Axel Lubk[1,2] and Daniel Wolf[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Germany

Vector field Electron Tomography (VFET) combines Electron Holography and Electron Tomography in the Transmission Electron Microscope (TEM) to reconstruct magnetic induction vector fields in 3D down to several nanometer resolution. In this tutorial we discuss the foundations of the technique, the practical workflow including pitfalls, and application to topical examples in nanomagnetism including domain walls in nanowires and skyrmion strings.

Tutorial MA 1.3 Sun 17:30 H4

3D magnetic imaging: an experimental window to study 3D magnetization at the nanoscale — •Aurelio Hierro-Rodriguez — Department of Physics, University of Oviedo,33007, Oviedo, Spain — CINN (CSIC-University of Oviedo) , 33940, El Entrego, Spain

The synergetic confluence of technological and scientific developments in nanofabrication and characterization techniques is paving the way towards the advance in Three-Dimensional Nanomagnetism, fuelled by the richness of phenomena and technological potential of the exploitation of the magnetization vector field in their natural dimensionality: three dimensions. In this lecture, a broad picture of the importance of the topic, in the framework of the novel physics that can be explored and exploited will be given, with a brief description of the methods that allow to fabricate almost any 3D magnetic geometry with nanometer resolution. The core of the lecture will deal with the advanced magnetic imaging techniques, which are opening a window towards the characterization of the full three-dimensional magnetization vector. Specifically, X-ray based magnetic vector tomography will be described and exemplified, showing the capabilities of the technique to volume resolve the magnetization vector field in arbitrary systems with nanometer resolution. These developments in vector magnetic imaging are making possible a change in the actual paradigm on how magnetization is characterized and studied at the nanoscale, by bringing a direct experimental probe to realize experimental micromagnetism.

MA 2: Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)

Time: Monday 9:30–12:15 Location: H16

MA 2.1 Mon 9:30 H16

Trilinear coupling and toroidicity in multiferroics — Andrea Urru[1] and •Vincenzo Fiorentini[2,3] — [1]Dept. of Physics, Rutgers University, USA — [2]Chair of Materials Science and Nanotech, TU Dresden — [3]Dept. Physics, University of Cagliary, Italy

We discuss the properties of the triple-order-parameter (ferromagnet, ferroelectric, ferrotoroid) layered-perovskite metal Bi5Mn5O17, as predicted from first-principles calculations, in the light of a Landau expansion with trilinear coupling, with particular reference to its multiple degenerate ground states with mutually orthogonal vector order parameters, giant cross-coupling magnetoelectricity, and magnetotoroidic effects.

MA 2.2 Mon 9:45 H16

Engineering magnetic domain wall energies in $BiFeO_3$ via epitaxial strain: A route to assess skyrmionic stabilities in multiferroics from first principles — •Sebastian Meyer[1,2], Bin Xu[3,4], Laurent Bellaiche[4], and Bertrand Dupé[1,2] — [1]Université de Liège, Belgium — [2]Fonds de la Recherche Scientifique, Belgium — [3]Soochow University, China — [4]University of Arkansas, USA

Epitaxial strain has emerged as a powerful tool to tune magnetic and ferroelectric properties in functional materials such as in multiferroic perovskite oxides. Here, we use first-principles calculations to explore the evolution of magnetic interactions in the antiferromagnetic multiferroic $BiFeO_3$ (BFO), one of the most promising multiferroics for future technology [1]. The epitaxial strain in BFO is varied between $\varepsilon \in [-2\%, +2\%]$. We find that both strengths of the exchange interaction and Dzyaloshinskii-Moriya interaction decrease linearly from compressive to tensile strain whereas the uniaxial magnetocrystalline anisotropy lifts the energy degeneracy of the (111) easy plane of bulk BFO. From the trends of magnetic interactions we can explain the destruction of cycloidal order in compressive strain as observed in experiments due to the increasing anisotropy energy. For tensile strain, we predict that the ground state remains unchanged as a function of strain. By using the domain wall energy, we envision a region where isolated chiral magnetic textures might occur as a function of strain [2].

[1] R. Ramesh, N. Spaldin, *Nature Mater* **6**, 21-29 (2007)
[2] S. Meyer *et al.*, *Phys. Rev. B* **109**, 184431 (2024)

MA 2.3 Mon 10:00 H16

Hidden order in Cr_2O_3 and α-Fe_2O_3 as a predictor for (anti-)magnetoelectricity — •Xanthe Verbeek[1,2], Andrea Urru[2,3], and Nicola Spaldin[2] — [1]Insitut für Physik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany — [2]Materials Department, ETH Zurich, 8093 Zürich, Switzerland — [3]Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854, USA

With first-principles calculations of Cr_2O_3 and α-Fe_2O_3, we show that the different magnetoelectric effects in these materials result from the ordering of hidden magnetic multipoles. We reveal for the first time anti-ferroically ordered magnetic multipoles in both Cr_2O_3, and isostructural α-Fe_2O_3, in which the global inversion symmetry is preserved by the different magnetic dipolar ordering. We can relate each of these multipoles and their ordering to linear, quadratic, and cubic (anti-) magnetoelectric effects, where in an anti-magnetoelectric effect the induced moments are ordered antiferromagnetically in the unit cell. We confirm the predicted induced moments using first-principles calculations, showing the lowest response in α-Fe_2O_3 a centrosymmetric magnetic material, to be a linear anti-magnetoelectric effect, revealing the presence of the magnetoelectric coupling despite the preserved global inversion symmetry. Our results demonstrate the existence of hidden magnetic multipoles leading to local linear magnetoelectric responses, even in centrosymmetric magnetic materials, and broaden the definition of magnetoelectric materials by including those showing such local magnetoelectric responses.

MA 2.4 Mon 10:15 H16

Non-trivial Spin Structures and Multiferroic Properties of the DMI-Compound $Ba_2CuGe_2O_7$ — •Peter Wild[1], Korbinian Fellner[1], Michał Dembski-Villalta[1], Markus Garst[2], Eric Ressouche[5], Tommy Kotte[3], Bertrand Roessli[4], Alexandra Turrini[4], and Sebastian Mühlbauer[1] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [2]Karlsruhe Institute of Technology, (KIT), Karlsruhe, Deutschland — [3]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [4]Paul Scherrer Institut (PSI), Villigen, Switzerland — [5]Institut Laue-Langevin (ILL), Grenoble, France

Antiferromagnetic $Ba_2CuGe_2O_7$, characterized by a quasi-2D structure with Dzyaloshinskii-Moriya interactions (DMI), is a non-centrosymmetric insulator that exhibits spiral spin structures with potential non-trivial topology and a variety of unconventional magnetic phase transitions. Below the Néel temperature $T_N = 3.05$K, the DMI term leads to a long-range incommensurate, almost AF cycloidal spin spiral in the ground state. Recently, a new phase with a vortex-antivortex magnetic structure has been theoretically described and experimentally confirmed in a pocket in the phase diagram at around 2.4K and an external field along the crystalline c-axis of around 2.2T. A lack of evidence for a thermodynamic phase transition towards the paramagnet in specific heat measurements and a finite linewidth in E and Q of the incommensurate peaks in neutron scattering, as opposed to the cycloidal ground state, seem to mark the vortex phase as a slowly fluctuating structure at the verge of ordering.

MA 2.5 Mon 10:30 H16

A comparison of Γ-point symmetries and phonon selection rules of spin-space and magnetic point group in $Co_2Mo_3O_8$ — •Onur Ercem[1], Felix Schilberth[1,2], Lilian Prodan[1], Vladimir Tsurkan[1], Alexander Tsirlin[3], István Kézsmárki[1], and Joachim Deisenhofer[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary — [3]Felix Bloch Institute for Solid-State Physics, Leipzig University, 04103 Leipzig, Germany

$Co_2Mo_3O_8$, which has recently come into the focus of research, as different magnetically ordered ground states can be formed and tuned by external magnetic fields or doping. $Co_2Mo_3O_8$ has a hexagonal structure, the polarization along the c-axis, and a collinear antiferromagnetic order below $T_N = 40$ K. Reflectivity measurements were performed using the FTIR spectrometer, in the frequency range from 100 to 8000 cm^{-1}, and the temperature range from 10 to 300 K could be covered. A preliminary analysis of the infrared-active modes for $E \parallel c$ reveals that 8 out of the 9 predicted A_1 modes are observed at the expected eigenfrequencies and the emergence of the mode at around 300 cm^{-1} below T_N. In $E \perp c$ at room temperature 10 modes were observed. Below T_N two new modes at 301 cm^{-1} and at 362 cm^{-1} observed. Comparison was made with lattice dynamical calculations.

MA 2.6 Mon 10:45 H16

Ferroelectric hafnium oxide-based multiferroic bilayers for magnetoelectric spin-orbit devices — •Maximilian Lederer, Johannes Hertel, Christoph Durner, Tatiana Gurieva, and Benjamin Lilienthal-Uhlig — Fraunhofer IPMS, Center Nanoelectronic Technologies, Dresden, Germany

This study investigates multiferroic heterostructures comprising $Hf_{0.5}Zr_{0.5}O_2$ (HZO) with Co/Pt top and TiN bottom electrodes on Si substrates. Using advanced deposition techniques, sub-nanometric thin films were fabricated. The research highlights achieving both ferroelectricity and perpendicular magnetic anisotropy simultaneously through a two-step annealing process. These properties are crucial for magnetoelectric spin-orbit (MESO) devices, which offer significant advantages such as lower power consumption and enhanced data storage capabilities. Insights into crystallization and diffusion processes were gained through various structural investigation methods. Additionally, the study demonstrates the manipulation of magnetic and ferroelectric domains using different microscopy techniques, underscoring the potential of MESO devices in next-generation electronic applications.

15 min. break

MA 2.7 Mon 11:15 H16

Internal fields at the V-sites and magnetic structure of

the lacunar spinel GeV_4S_8 — •Thomas Gimpel[1], Norbert Büttgen[1], Hiroyuki Nakamura[2], Vladimir Tsurkan[1], and István Kézsmárki[1] — [1]University of Augsburg — [2]Graduate School of Engineering, Kyoto

GeV_4S_8 is a multiferroic lacunar spinel that undergoes both structural (T_{JT}=30 K) and magnetic (T_N=13 K) transitions upon which the four V-sites of the V_4 tetrahedra that are equivalent in the cubic phase transform into three distinct sets of V-sites with zero-field ^{51}V NMR frequencies of 21.7, 53.6 and 65.6 MHz. This indicates that only two V-sites have the same internal magnetic field, while the other two have different ones. Based on the angular dependence of the resonance field upon the rotation of the field, we conclude that the direction of the internal field is common for the four V-sites and is parallel to one of the cubic [110]-type axes, which indicates that the magnetic space group is $Pmn2_1$.

MA 2.8 Mon 11:30 H16

Fast control of antiferromagnetic domains via pulsed electric fields in *Co_3O_4* — •Isabel Täuber, Maximilian Winkler, Somnath Ghara, Lilian Prodan, and Istvan Kezsmarki — Universität Augsburg, Deutschland

Co_3O_4 shows the linear magnetoelectric effect below the Neel-temperature of 30K, with a large magnetoelectric coefficient of 14 ps/m. Besides the typical control of the AFM state by colling with electric and magnetic fields across TN, the domains can be switched by voltage pulses as short as a few ns far below the transition temperature. To improve the application ability, we focus on switching of thin films of Co_3O_4 single crystals, paving the way for the next generation of spintronics.

MA 2.9 Mon 11:45 H16

Anomalously strong magnetoelectric coupling in hexaferrite films — •Jakub Vít[1], Kwang-Tak Kim[2], Hyunju Hwang[2], Radomír Kužel[3], Milan Dopita[3], Darina Smržová[4], Kee Hoon Kim[2], and Josef Buršík[4] — [1]Institute of Physics, Czech Academy of Sciences, Czechia — [2]Center for Novel States of Complex Materials Research, Seoul National University, Korea — [3]Faculty of Mathematics and Physics, Charles University, Czechia — [4]Institute of Inorganic Chemistry, Czech Academy of Sciences, Czechia

Bulk hexaferrites are well known to exhibit strong magnetoelectric (ME) effects, often extending up to room temperature. In contrast, ME properties of hexaferrite films have been investigated only in a single recent study: In Z-hexaferrite films, the ME effect was found significantly stronger than in a crystal. [1] We continued this research by studying Y-hexaferrite films $Ba_{2-x}Sr_xCo_2Fe_{11.1}Al_{0.9}O_{22}$ on $SrTiO_3$ (111), grown by chemical solution deposition. For x=1, the magnetic-field-induced polarization reached 6.5 mC/m^2 at 10 K , i.e. 10x more than in the Z-hexaferrite films [1] and 50x more than in Y-hexaferrite crystals. [2] To elucidate these intriguing observations, microstructure of the films was studied in detail by real (SEM, TEM) and reciprocal (XRD) space techniques. Possible influence of the substrate on ME measurements was also taken into account.

[1] K. Shin et al., *Adv. Electron. Mater.* 2101294, (2022) [2] C. B. Park, et al., *Phys. Rev. Mater.* **5**, 034412 (2021)

MA 2.10 Mon 12:00 H16

Higher-order Magnetizations of Non-centrosymmetric Antiferromagnets — •Michael Paulsen[1], Silvia Knappe-Grüneberg[1], Jens Voigt[1], Allard Schnabel[1], Rainer Körber[1], Michael Fechner[2], Ivan Ushakov[3], and Dennis Meier[3] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg, Germany — [3]NTNU Norwegian University of Science and Technology, Trondheim, Norway

Antiferromagnetic materials lack macroscopic magnetic dipole fields, due to their compensated magnetic spin texture. In his seminal work, Dzyaloshinskii predicted that higher-order magnetization contributions arise in non-centrosymmetric antiferromagnets, in particular quadrupolar magnetic field contributions, and first experimental data suggested the presence of such fields in the antiferromagnetic model system Cr_2O_3. Here, we present calculations and measurements gained at cryogenic and room temperature using Superconducting Quantum Interference Devices (SQUIDs) and Optically Pumped Magnetometers (OPMs) setups, respectively, in ultra-low magnetic field environments. The results demonstrate the existence of quadrupolar far-fields and characteristic signatures in different classes of antiferromagnets. Importantly, our SQUID-based approaches are universal and can be applied to a wide range of systems, establishing new methods for characterizing materials with ultra-small magnetic remanence in general.

MA 3: Magnonics I

Time: Monday 9:30–13:00 Location: H18

MA 3.1 Mon 9:30 H18

Floquet Magnons in a Periodically-Driven Magnetic Vortex — •Christopher Heins[1,2], Luaks Körber[1,2,3], Joo-Von Kim[4], Thibaut Devolder[4], Johan Mentink[3], Attila Kákay[1], Katirn Schultheiss[1], Jürgen Fassbender[1,2], and Helmut Schultheiss[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Radboud University, Institute of Molecules and Materials, Nijmegen, The Netherlands — [4]Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Saclay, Palaiseau, France

Magnetic vortices are prominent examples of topology in magnetism with a rich set of dynamic properties. They exhibit an intricate magnon spectrum and show an eigen-resonance of the vortex texture itself, the gyration of the vortex core. The fundamental modes of both excitation types are separated in their resonance frequencies. While the vortex typically gyrates at a few hundred MHz, the magnon modes typically have frequencies in the lower GHz range. Under the influence of a periodic driving field, Floquet states emerge due to a temporal periodicity imposed on the system's ground state by the gyration, much like the formation of Bloch states in the periodic potential of a crystal lattice. While Bloch states are shifted in momentum space, Floquet states are shifted in energy by multiples of the drive frequency.

MA 3.2 Mon 9:45 H18

Nanoscale YIG-Based Magnonic Crystals — •Khrystyna Levchenko[1], Kristýna Davídková[1], Mathieu Moalic[2], Carsten Dubs[3], Michal Urbánek[4], Qi Wang[5], Maciej Krawczyk[2], and Andrii Chumak[1] — [1]University of Vienna, Austria — [2]A. Mickiewicz University, Poland — [3]INNOVENT, Germany — [4]CEITEC Nano, Czech Republic — [5]Huazhong University, China

Magnonic crystals (MCs) are a spin-wave (SW) based class of artificial magnetic materials characterised by a spatially periodic variation of their properties. The combination of design flexibility and SW intrinsic advantages makes MCs promising candidates for RF applications, although multi-mode SW propagation disturbs the operating characteristics. To overcome this, it is necessary to work with nanostructures in the single-mode regime. Leveraging recent progress in materials science and fabrication techniques, we have realised 1D MCs from 100 nm thick epitaxial yttrium iron garnet (YIG) films. The MCs were developed using electron beam lithography, ion etching and evaporation, with periodicities of 1 μm and optimised notches (100-250 nm depth) or antidots (100-150 nm diameter). Microstrip antennae were used for SW excitation and detection. Experimental characterisation using micro-focused Brillouin light scattering and propagating spin-wave spectroscopy, supported by simulations (TetraX), confirmed efficient single-mode SW transport over a distance of 10 μm and bandgap formation. These results pave the way for further advances, such as 2D arrays with magnon guidance and topologically protected magnon transport - a milestone yet to be achieved experimentally.

MA 3.3 Mon 10:00 H18

The impact of local exchange bias on the dyanmics in chiral antiferromagnetic Mn_3Ir heterostructures with a $Ni_{80}Fe_{20}$ — •Rouven Dreyer[1], James M. Taylor[1], Stuart Parkin[2], and Georg Woltersdorf[1,2] — [1]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 exhibit the intrinsic spin Hall effect (SHE) and to provide exchange bias (EB) in multilayer system, rendering these AFs interesting candidates for spintronic applications. However, the role of the chiral domain structure in this process and the transmission of the resulting spin current across interfaces with ferromagnets (FMs), remain open questions. Using a combination of integrative spin-torque ferromagnetic resonance (ST-FMR) and super-Nyquist-sampling magneto-optical Kerr effect (SNS-MOKE) measurements, we investigate the impact of the noncollinear spin texture of the Mn_3Ir on the magnetization dynamics in heterostructures with $Ni_{80}Fe_{20}$. Here, we show a strong discrepancy between local and integrative techniques due to interfacial exchange coupling between the AF and the FM. As a result of this, only SNS-MOKE studies allow for a local detection of the SHE. Furthermore, we obtain modifications of the magnetization dynamics strongly depending on the direction of applied EB. Moreover, we demonstrate that a combination of small bias fields and current-induced heating acts as an efficient control mechanism for setting of the exchange bias und thus for changing the magnetization dynamics during the measurements.

MA 3.4 Mon 10:15 H18

Evoution of coherence in magnonic BECs — •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 process of formation of a coherent magnon-Bose-Einstein condensate (BEC) in an over-populated, hot magnon gas has recently been intensively studied. We have already demonstrated an electromagnetic detection scheme that allows direct evaluation of the phase correlation in the BEC. We have now extended the setup to study the evolution of the phase coherence during and after the formation of a homogeneous excitation of the magnon system - a BEC. In our experiments we use a perpendicularly magnetized yttirumiron-garnet film, which is parametrically pumped. This allows us to further demonstrate that coherence arises even though the magnon gas is still heated by the pumping. Furthermore, due to the phase sensitivity of our technique, we observe the spontaneous emergence of a random phase of the BEC without any influence of external factors.

This research was funded by the Deutsche Forschungsgemeinschaft in frame of TRR 173/2*268565370 Spin+X (Project B04).

MA 3.5 Mon 10:30 H18

Ultra-long magnon lifetime in the quantum limit — •Rostyslav O. Serha[1], Kaitlin H. McAllister[2], Fabian Majcen[1], Sebastian Knauer[1], Timmy Reimann[3], Carsten Dubs[3], Gennadii A. Melkov[4], Alexander A. Serga[5], Vasyl S. Tyberkevych[6], Dmytro A. Bozhko[2], and Andrii V. Chumak[1] — [1]University of Vienna, Vienna, Austria — [2]University of Colorado, Colorado Springs, USA — [3]INNOVENT e. V. technology development, Jena, Germany — [4]National Taras Shevchenko University, Kyiv, Ukraine — [5]RPTU, Kaiserslautern, Germany — [6]Oakland University, Rochester, USA

Quantum magnonics seeks to harness the quantum mechanical properties of magnons for quantum information technologies. A major bottleneck in this field is the limited magnon lifetime, which constrains the performance of quantum magnonic systems. In this study, we investigated yttrium iron garnet (YIG) spheres with varying impurity levels using ferromagnetic resonance (FMR) spectroscopy to examine magnon lifetimes at millikelvin temperatures. For k=0 magnon modes, lifetimes of up to one microsecond were observed. Remarkably, a specialized three-magnon splitting experiment revealed lifetimes of short-wavelength dipole magnons to be up to an order of magnitude longer than their k=0 counterparts. We report a maximum magnon lifetime of 18 microseconds at a frequency of 1.6 GHz. These findings offer crucial insights into the mechanisms influencing magnon lifetimes and pave the way for quantum magnonic devices featuring long-lived propagating magnons.

MA 3.6 Mon 10:45 H18

Exotic Magnon Spectra from Strong Dipolar Interactions and Anisotropy — •Konrad Scharff — KIT, Karlsruhe, Deutschland

Magnetic dipole-dipole interactions on lattices have been known to be the source of non-analytical behaviour of associated spin wave dispersions at and around the Brillouin zone center [1,2]. We investigate the consequences and predicted signatures of said non-analyticity in a 3D hexagonal lattice model that additionally hosts magnetic exchange interaction, as well as an easy-plane on-site anisotropy. Dynamical susceptibilities are theoretically evaluated and compared to available experimental data.

[1] Jensen, J. and Mackintosh, A.R. Rare Earth Magnetism. Clarendon Press - Oxford (1991)

[2] Baehr, M. et al. Effect of magnetic dipolar interactions on the interchain spin-wave dispersion in CsNiF3. Phys. Rev B 54, 12932 (1996)

MA 3.7 Mon 11:00 H18

Machine learning tool for inelastic neutron scattering: The case of CrSBr — •Nihad Abuawwad[1], Yixuan Zhang[2], Hongbin Zhang[2], and Samir Lounis[1,3] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, Jülich, Germany — [2]Institute of Materials Science, Technical University Darmstadt, Darmstadt , Germany — [3]Institute of Physics, University of Halle, Halle, Germany

Spin waves, or magnons, are fundamental excitations in magnetic materials that provide insights into their dynamic properties and interactions. Magnons are the building blocks of magnonics, which offer promising perspectives for data storage, and quantum computing. These excitations are typically measured through Inelastic Neutron Scattering (INS) techniques, which involve heavy and time-consuming measurements, data processing, and analysis based on various theoretical models. Here, we introduce a machine learning algorithm that integrates adaptive noise reduction and active learning sampling, which enables the restoration from minimal INS point data of spin wave information and the accurate extraction of magnetic parameters, including hidden interactions. Our findings, benchmarked against the magnon spectra of CrSBr, significantly enhance the efficiency and accuracy in addressing complex and noisy experimental measurements. This advancement offers a powerful machine-learning tool for research in magnonics and spintronics, which can also be extended to other characterization techniques at large facilities[1].

[1] Abuawwad N. arxiv:2407.04457 (2024)

15 min. break

MA 3.8 Mon 11:30 H18

Thermally Induced Demagnetizing Fields: Effective Potentials for Magnon Bose–Einstein Condensates — •Matthias R. Schweizer[1], Franziska Kühn[1], Victor S. L'vov[2], Anna Pomyalov[2,3], Georg von Freymann[1,4], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern — [2]Department of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [4]Fraunhofer Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern

We investigate the control of magnon Bose–Einstein condensates (mBEC) by means of reconfigurable potentials. It is shown that the localized decrease of the saturation magnetization leads to strong demagnetizing fields which elevate the resonance frequency of magnons in the mBEC state at the bottom of the spin-wave spectrum. Consequently, spatially varying magnetization and field profiles act as space-modulated potentials, determining the dynamics of the mBEC. For the experimental observation, we create reconfigurable microscopic magnetization profiles using laser heating controlled by optical wavefront modulation. Electromagnetic parametric pumping is used to increase the magnon gas density and Brillouin light scattering spectroscopy is employed to detect the mBEC dynamics. This research was supported by the DFG–TRR 173-268565370 Spin+X (Project B04).

MA 3.9 Mon 11:45 H18

Fluctuations of the inverted magnetic state and how to sense them — •Anna-Luisa Römling[1], Artim Bassant[2], and Rembert Duine[2] — [1]Condensed Matter Physics Center (IFIMAC) and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [2]Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands

Magnons are the low-energy exciations of magnetically ordered materials. While the magnetic moment of a ferromagnet below Curie tempertature aligns with an applied magnetic field, recent theoretical work has demonstrated that the magnetic order can be inverted by pumping spin orbit torque into the magnet. This results in an energetically unstable but dynamically stabilized state where the magnetic moment is antiparallel to an applied magnetic field. The excitations on such a state have negative energy and are called antimagnons, the antiparticle of the magnon. Here, we theoretically study the quantum and classical fluctuations of the inverted magnetic state and their sigatures in experimental set-ups. Our results advance the understanding of fundamental properties of antimagnons as well as experimental data related to the inverted magnetic state. They pave the way for exciting applications in spintronics and magnonics.

MA 3.10 Mon 12:00 H18

Inductive noise spectroscopy of thermally excited magnons — Luise Holder[1], Richard Schlitz[1], Jamal Ben Youssef[2], Christian Runge[1], Akashdeep Kamra[3,4], William Legrand[5], Hans Huebl[6,7,8], •Michaela Lammel[1], and Sebastian T.B. Goennenwein[1] — [1]Universität Konstanz, Konstanz — [2]LabSTICC-CNRS, Université Bretagne Occidentale, Brest — [3]RPTU Kaiserslautern-Landau, Kaiserslautern — [4]Universidad Autónoma de Madrid, Madrid — [5]CNRS, Institute Néel, Université Grenoble Alps, Grenoble — [6]Walther-Meißner-Institut, Garching — [7]Technische Universität München, Garching — [8]Munich Center for Quantum Science and Technology, Munich

For the identification of non-classical (squeezed) magnon states, quantitative knowledge about thermal or vacuum fluctuations of the magnetization is essential. We show that thermal magnetization fluctuations of a ferromagnetic thin film can be sensitively characterized using inductive magnon noise spectroscopy (iMNS). Our broadband approach based on a coplanar waveguide and a commercial spectrum analyzer allows to detect the microwave emission of the equilibrium magnetization fluctuations relative to a cold microwave background. Modeling the response of the whole microwave system and comparing it quantitatively with low-power broadband ferromagnetic resonance measurements in linear response yields excellent agreement, which verifies the equilibrium character of the iMNS. Thus, our work establishes a purely inductive broadband access to the equilibrium properties of magnetization fluctuations.

MA 3.11 Mon 12:15 H18

Threshold of parametric instability of magnons in different magnetization geometries under quasi-continuous pumping — •Tamara Azevedo[1], Rostyslav O. Serha[2], Matthias R. Schweizer[1], Vitaliy I. Vasyuchka[1], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Faculty of Physics, University of Vienna, 1090 Vienna, Austria

Parametric electromagnetic pumping of magnons is a key method for exciting and amplifying spin waves. Measuring the threshold of parametric instability, where energy input overcomes magnon damping, is crucial. Using a sensitive, automated technique with a quasi-continuous wave generated by a vector network analyzer, we measured this threshold in tangentially magnetized yttrium iron garnet films. Two geometries were studied: a microstrip pumping resonator aligned parallel and perpendicular to the external magnetization field $\mathbf{H}_0$. The threshold power as a function of $\mathbf{H}_0$ shows a sawtooth structure, likely caused by wave vector quantization of parametric magnons. In the perpendicular geometry, threshold power peaks suggest magnon-phonon hybridization with longitudinal, transverse, and surface acoustic modes. These results underline the role of magnetization geometry in determining parametric instability thresholds, providing guidance for optimizing spintronic and magnonic devices. This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)*TRR 173*268565370 Spin+X (Project B04).

MA 3.12 Mon 12:30 H18

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[1,2], Philipp Pirro[1], John Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern, Germany — [2]University of Oxford, United Kingdom

Magnon-based devices provide a promising approach for energy-efficient computation due to low intrinsic losses in materials such as yttrium-iron-garnet (YIG). Here we show that surface acoustic waves (SAWs) can be used for the excitation of spin waves in hybrid ferrimagnetic/piezoelectric devices. The SAW thereby couples to magnons under conservation of energy and momentum [1,2].
We studied the excitation and propagation behavior of surface acoustic waves in GGG/YIG/ZnO-heterostructures [3] by electrical and micro-focused optical techniques. The phonon-magnon coupling in YIG is investigated by performing SAW transmission measurement as a function of the magnetic field 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] Küß et al., Frontiers in Physics 10, 981257 (2022)
[2] Kunz et al., Appl. Phys. Lett. 124 152403 (2024)
[3] Ryburn et al., arXiv 2403.030006 (2024)

MA 3.13 Mon 12:45 H18

Spatial control of hybridization-induced spin-wave transmission stop band — •Franz Vilsmeier[1,2], Christian Riedel[1], and Christian Back[1] — [1]Technische Universität München — [2]Universität Wien

Spin-wave (SW) propagation close to the hybridization-induced transmission stop band is investigated within a trapezoid-shaped 200 nm thick yttrium iron garnet film using time-resolved magneto-optic Kerr effect microscopy. The gradual reduction of the effective field within the structure leads to local variations of the SW dispersion relation and results in a SW hybridization at a fixed position in the trapezoid, where the propagation vanishes since the SW group velocity approaches zero. By tuning the external field or frequency, spatial control of the spatial stop band position and spin-wave propagation is demonstrated.

MA 4: Electron Theory of Magnetism and Correlations

Time: Monday 9:30–11:45 Location: H19

MA 4.1 Mon 9:30 H19

Tunable Half-Metallicity and Ferromagnetism in Gated single layer g-C3N4 via Nitrogen Lone Pair Depletion. — •Pietro Nicolò Brangi, Francesca Martini, Pier Luigi Cudazzo, and Matteo Calandra — Department of Physics, University of Trento, Via Sommarive 14, 38123 Povo, Italy

Graphitic carbon nitride (g-C3N4) is a promising catalyst for water splitting and hydrogen production, with nitrogen lone pairs arising from broken carbon-nitrogen bonds in its heptazine structure. These strongly localized and weakly hybridized lone pairs form ultraflat bands potentially leading to correlated states when doped.

Using first-principles calculations, we show that field-effect hole-doping in single-layer g-C3N4 depletes these lone pairs, generating ultraflat bands at the Fermi level and unveiling a rich phase diagram. At low hole concentrations, a half-metallic state emerges with tunable magnetization, increasing linearly with carrier density and reaching up to 1 Bohr magneton /3 f.u.. At an integer filling of one hole per cell, a band-insulating ferromagnetic state is stabilized, followed by an interplay of metallic and half-magnetic phases with further doping, ultimately leading to a second ferromagnetic insulating state.

Our work highlights nitrogen-based lone-pair systems as a novel platform for strongly correlated states, with implications for magnetism even at small electric fields, hinting at unexplored potential in photocatalysis.

MA 4.2 Mon 9:45 H19

Investigation of crystalline environment for Fe oxides using XAS and XPS:A DFT+MLFT approach — •Hamza Zerdoumi, Ruiwen Xie, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt,Germany

Fe oxides are versatile materials with applications spanning catalysis, memory storage, and photoelectrochemical decomposition of seawater for clean hydrogen production. Taking Fe_2O_3 as an example, there exist five distinct phases, i.e., α-Fe_2O_3, β-Fe_2O_3, γ-Fe_2O_3, ϵ-Fe_2O_3, and ζ-Fe_2O_3, each exhibiting unique properties. Therefore, it is intriguing to clarify how the local crystalline environment can shape the electronic structure and hence tailor the corresponding functionalities. In this study, we simulate X-ray photoelectron spectroscopy (XPS) and X-ray absorption spectroscopy (XAS) spectra using a combination of density functional theory (DFT) and multiplet ligand field theory (MLFT). By analyzing individual spectral bands corresponding to iron sites in various crystal structures, we examine the correlation between local symmetry and the simulated spectra. Our work highlights how variations in local environments influence the spectroscopic features of iron oxide polymorphs, offering valuable insights into their diverse properties.

MA 4.3 Mon 10:00 H19

Domain wall engineering in distorted Kagome magnet — •Avdhesh Kumar Sharma[1], Premakumar Yanda[1], Samuel Harrison Moody[2], Chandra Shekhar[1], and Claudia Felser[1] — [1]Max Planck Institute for chemical physics of solids, 01187 Dresden, Germany — [2]Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institute, CH-5232 Villigen, Switzerland

In condensed matter, Kagome material can host interplay of nontrivial topology, correlations, and magnetism due to their unique lattice and band structure. Recently, RTX series with ZrNiAl structure have gained attention due to possessing kagome lattice continuously breaking translation symmetry i.e., distorted kagome lattice. Intriguingly, HoAgGe has been predicted to have a kagome spin ice state and break the the reversal like symmetry and show two degenerate states in anomalous Hall effect. Along this line, we have synthesized single crystals of TbAgGe to investigate the magnetic and electrical transport properties in detail. It crystallizes in a hexagonal crystal structure with space group P-62m. It exhibits long-range AFM ordering of Tb3+ ions at Néel temperatures 29K, 25K and 20K. Further, it shows metamagnetic transitions when H || c, which might result in a non-coplanar spin structure in the system and goes to ferromagnetic (FM) state at high fields. Moreover, it shows significant anomalous Hall effect near the metamagnetic transitions, which is attributed to originating from the magnetic domain walls. Our findings suggest that RTX family with distorted kagome lattice can be an excellent platform to study the interplay of domain wall magnetism and topology.

MA 4.4 Mon 10:15 H19

Magnetic-circular dichroism on low-lying excitations in antiferromagnetic Fe2Mo3O8 — •Kirill Vasin[1], Istvan Kézsmárki[1], Sándor Bordács[2], and Joachim Deisenhofer[1] — [1]University of Augsburg, Augsburg, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary

We report the observation of a strong magnetic circular dichroism (MCD) and Faraday effect in the polar honeycomb antiferromagnet $Fe_2Mo_3O_8$ in the terahertz (THz) range. Using a common linear detection scheme with polarizers on both the emitter and detector set to the same angle, we observe seemingly thickness-dependent features and broadening in the transmission spectrum near narrow resonances in the Faraday configuration. These features are absent in the Voigt geometry with the same static magnetic field configuration, confirming that they arise from Faraday rotation (or MCD). By analyzing the zero-field spectrum and fitting Lorentz oscillators in the time-domain, we resolved oscillators parameters of the observed strong and narrow THz excitations with high accuracy. Using these parameters, we successfully reconstructed our field- and thickness-dependent transmission spectra, highlighting the role of Faraday rotation in the observed phenomena.

Our findings demonstrate the importance of considering detection schemes in Time-Domain THz spectroscopy and provide insights into methods of measuring MCD and Faraday rotation without ellipsometry techniques in «single-shot» transmission measurements for aniferromagnets.

MA 4.5 Mon 10:30 H19

Pressure-induced effects on the electronic band topology, magnetic order, and transport properties in FeSn — •Artem Chmeruk[1], Lilian Prodan[2], and Liviu Chioncel[3] — [1]University of Augbusrg — [2]University of Augbusrg — [3]University of Augbusrg

The family of kagome metals offers a fruitful platform for investigating the interplay between electronic band structure topology and various properties such as magnetism, electrical and optical response, etc. A rather promising topic of research is to control the positions of various topological features such as band (anti-) crossings of different dimensions (nodal points, lines, etc.) by some external parameters. For example, applying an external magnetic field could lead to band reconsctruction and therefore move the band crossings to different locations in the BZ. In a similar fashion, external pressure provides an opportunity to control these topological features both in terms of their location in the momentum space and on the energy scale. The possibility of moving such crossings closer to the Fermi level would immediately have an effect on the various observable quantities such as anomalous Hall conductivity. In this work, we study the effect of pressure on the magnetic order and the electronic band structure in FeSn up to 10 GPa. Furthermore, we investigate changes in the Berry curvature and its influence on the transport properties.

MA 4.6 Mon 10:45 H19

Emergent Majorana Metal from a Chiral Spin Liquid — •Shi Feng[1,2], Penghao Zhu[2], Kang Wang[3], Tao Xiang[3], and Nandini Trivedi[2] — [1]Technical University of Munich, Garching, Germany — [2]The Ohio State University, Columbus, USA — [3]Institute of Physics, Chinese Academy of Sciences, China

We propose a novel mechanism to explain the emergence of an intermediate gapless spin liquid phase (IGP) in the antiferromagnetic Kitaev model in an externally applied magnetic field, sandwiched between the well-known gapped chiral spin liquid (CSL) and the gapped partially polarized (PP) phase. We propose in moderate fields π-fluxes nucleate in the ground state and trap Majorana zero modes. As these fluxes proliferate with increasing field, the Majorana zero modes overlap creating an emergent Z_2 Majorana metallic state with a 'Fermi surface' at zero energy. We further show that the Majorana spectral function captures the dynamical spin and dimer correlations obtained by the infinite Projected Entangled Pair States (iPEPS) method thereby validating our variational approach. The emergence of the IGP as a Majorana metal at zero temperature indicates a new class of gapless QSLs alongside the commonly recognized Dirac spin liquids and $U(1)$

spinon Fermi surfaces in prevailing theories, bringing new insights into the nature of various candidate QSL phases of matter stabilized by moderate magnetic fields.

MA 4.7 Mon 11:00 H19

Tuning the order of a deconfined quantum critical point — Anika Goetz[2], •Natanael C. Costa[1], and Fakher Assaad[2] — [1]Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil — [2]Institut für Theoretische Physik und Astrophysik, Universitat Würzburg, Würzburg, Germany

We consider a Su-Schrieffer-Heeger model in the assisted hopping limit where direct electron hopping is subdominant. At fixed electron-phonon coupling and in the absence of Coulomb interactions the model shows a deconfined quantum critical point between a $(0, \pi)$ valence bond solid in the adiabatic limit and a quantum antiferromagnetic (AFM) at high phonon frequencies. Here we show that by adding terms to the model that reinforce the AFM phase, thereby lowering the critical phonon frequency, the quantum phase transition becomes strongly first order. Our results does not depend on the symmetry of the model. In fact by adding a Hubbard-U term to the model lowers the $O(4)$ symmetry to SU(2), such that the DQCP we observe has the same UV symmetries as other models that account for the same quantum phase transitions.

MA 4.8 Mon 11:15 H19

The Laughlin vortex crystal in ideal Chern bands — •Saranyo Moitra and Inti Sodemann — Leipzig University, Leipzig, Germany

We have uncovered a novel phase transition of the celebrated Laughlin Fractional quantum Hall wave-function from its topologically ordered fluid phase onto a power-law-correlated vortex crystal in flat Chern bands with ideal quantum geometry. We will present a theory of ground state correlations and collective modes of these states across this transition and discuss their potential relevance to anomalous fractional quantum Hall phenomena in platforms such as moiré MoTe2, twisted bilayer graphene and pentalayer graphene.

MA 4.9 Mon 11:30 H19

Forestalled Phase Separation as the Precursor to Stripe Order — •Aritra Sinha and Alexander Wietek — Max Planck Institute for the Physics of Complex Systems, Nothnitzer Strasse 38, Dresden 01187, Germany

Stripe order is a prominent feature in the phase diagram of the high-temperature cuprate superconductors and has been confirmed as the ground state of the two-dimensional Fermi Hubbard model in certain parameter regimes. Upon increasing the temperature, stripes and the superconducting state give way to the enigmatic strange metal and pseudogap regime, whose precise nature poses long-standing, unresolved puzzles. Using modern tensor network techniques, we discover a crucial aspect of these regimes. Infinite projected entangled pair state (iPEPS) simulations in the fully two-dimensional limit reveal a maximum in the charge susceptibility at temperatures above the stripe phase. This maximum is located around hole-doping p=1/8 and intensifies upon cooling. Using minimally entangled typical thermal states (METTS) simulations on finite cylinders, we attribute the enhanced charge susceptibility to the formation of charge clusters, reminiscent of phase separation where the system is partitioned into hole-rich and hole-depleted regions. In contrast to genuine phase separation, the charge cluster sizes fluctuate statistically without a divergent charge susceptibility. Hence, while this precursor state features clustering of charge carriers, true phase separation is ultimately forestalled at lower temperatures by the onset of stripe order.

MA 5: Focus Session: Magnetic Phenomena from Phonon Chirality and Angular Momentum I (joint session MA/TT)

The magnetic moment of the electron lies at the heart of magnetism and spintronics. However, recent research has unveiled the angular momentum and magnetic moment of chiral phonons as fundamental quantities in their own right. These chiral phonons give rise to a plethora of novel lattice phenomena analogous to electronic effects, such as the phonon Hall and phonon Zeeman effects. Moreover, they play a critical role in angular momentum transfer on ultrafast timescales, as seen in the Einstein-de Haas effect. Chiral phonons can also generate effective magnetic fields reaching the tesla scale, inducing magnetization in antiferromagnetic, paramagnetic, and even nonmagnetic materials - a phenomenon reminiscent of the Barnett effect. These advancements showcase phonon chirality and angular momentum as powerful emerging tools for generating and controlling magnetism. This focus session aims to highlight the latest breakthroughs in chiral-phonon magnetism and foster connections between the rapidly evolving field of chiral phononics and the broader magnetism research community.

Coordinators: Dominik M.Juraschek, Eindhoven University of Technology, d.m.juraschek@tue.nl; Martina Basini, ETH Zürich, m.basini@ethz.ch

Time: Monday 9:30–13:00 Location: H20

Invited Talk MA 5.1 Mon 9:30 H20

Driving Coherent Phonon-Phonon Angular Momentum Transfer via Lattice Anharmonicity — •Sebastian Maehrlein — Fritz Haber Institute of the Max Planck Society — Helmholtz Zentrum Dresden Rossendorf — TU Dresden

The discrete rotational symmetry of crystal structures leads to the conservation of quantized angular momentum in solids. Whereas the exchange of energy and linear momentum between lattice vibrations (phonons) via anharmonic coupling is a cornerstone of solid-state physics, conservation and transfer of angular momentum within the lattice remained a postulate, yet. Recently, phonon angular momentum, often in the form of chiral phonons, was linked to gigantic magnetic fields, dynamical ferroelectricity, ultrafast demagnetization, or magnetic switching. However, the fundamental process of phonon to phonon angular momentum transfer required for demagnetization and other spin-related relaxation phenomena remained elusive.

Here we drive coherent phonon-phonon angular momentum transfer by establishing helical nonlinear phononics. Thereby, we directly observe phonon helicity-switching dictated by (pseudo) angular momentum conservation and the discrete rotational symmetry of the lattice. Ab-initio modeling in conjunction with classical equations of motion confirm the experimentally observed anharmonic phonon-phonon coupling as the dominating lattice angular momentum transfer channel. Our results thus open the field of helical or chiral nonlinear phononics, turning lattice angular momentum into the long missing tuning knob for ultrafast material control.

Invited Talk MA 5.2 Mon 10:00 H20

Chiral phonons, phono-magnetism, and spin-rotation coupling — •Matthias Geilhufe — Department of Physics, Chalmers University of Technology, 412 96 Göteborg, Sweden

High-intensity THz lasers enable the coherent excitation of individual phonon modes. The ultrafast control of emergent magnetism through phonons and phonon angular momentum opens new avenues for tuning functional materials. Recent experiments suggest a substantial magnetization in various materials [1,2], presenting a challenge for theoretical modeling. I will provide an introduction to magnetization induced by phonon angular momentum via the phonon inverse Faraday effect [3]. Additionally, I will discuss a coupling mechanism based on inertial effects, which facilitates the interaction between rotational degrees of freedom and electron spin [4].

[1] Basini et al., Nature, 628, 534 (2024)
[2] Davies et al., Nature, 628, 540 (2024)
[3] Shabala, Geilhufe, Physical Review Letters, arXiv:2405.09538
[4] Geilhufe, Physical Review Research, 4, L012004 (2022)

Invited Talk MA 5.3 Mon 10:30 H20

Geometry of temporal chiral structures and photoinduced chirality-spin coupling — •Olga Smirnova[1,2,3], Philip Flores[1], Aycke Roos[1], David Ayuso[4], Piero Decleva[5], Stefanos Carlstroem[1], Serguei Patchkovskii[1], and Andres Ordonez[4] — [1]Max-Born Institute, Berlin — [2]Technische Universität Berin — [3]Technion - Israeli Institute of Technology, Haifa, Israel — [4]Imperial College London, UK — [5]CNR IOM and Dipartimento di Scienze Chimiche e Farmaceutiche, Universita degli Studi di Trieste, Italy

In non-relativistic physics the concepts of geometry and topology are usually applied to characterize spatial structures, or structures in momentum space. We introduce the concept of temporal geometry [1], which encompasses geometric and topological properties of temporal shapes, e.g. trajectories traced by a tip of a time-dependent vector on sub-cycle time scale, and apply it to light-driven ultrafast electron currents in chiral molecules. The geometric concepts: curvature and connection emerge as ubiquitous features of photoexcited chiral electron dynamics. To demonstrate the link between the geometric fields and spin, we extend the concept of curvature to spin-resolved photoionization, and show that it is responsible for enantio-sensitive locking of the cation orientation to the photoelectron spin. This translates into chirality induced spin selectivity in photoionization of oriented chiral molecules both in one photon and two-photon processes.

[1] Geometry of temporal chiral structures, A. F. Ordonez, A. Roos, P. Mayer, D.Ayuso, O. Smirnova, arXiv preprint arXiv:2409.02500, 2024

15 min. break

Invited Talk MA 5.4 Mon 11:15 H20

Phonon thermal Hall effect — •Kamran Behnia — Ecole Supérieure de Physique et de Chimie Industrielles, Paris, France

In insulating solids and liquids, heat is carried by phonons. The phonon scattering time is close to the so-called Planckian time near the melting temperature. It increases with cooling, as phonon-phonon Umklapp scattering events rarefy. A rigorous determination of thermal conductivity of insulators from first principles has been a major accomplishment of the quantum theory of solids. In contrast, our understanding of momentum and energy exchange between phonons at low temperatures is imperfect. In this context, the experimental detection of phonon thermal Hall effect in a growing number of insulators is a challenge to the condensed matter theory. The list now includes elemental insulators, such as black phosphorus, silicon and germanium, in which the spin degree of freedom is irrelevant and the atomic bonds are covalent. We will examine how magnetic field can influence anharmonicity.

Invited Talk MA 5.5 Mon 11:45 H20

Giant effective magnetic moment of chiral phonons — •Swati Chaudhary[1,3], Dominik Juraschek[2], Martin Rodriguez-Vega[3], and Gregory A Fiete[4] — [1]The Institute for Solid State Physics, The University of Tokyo, Japan — [2]Eindhoven University of Technology, Eindhoven, Netherlands — [3]The University of Texas at Austin, Austin, USA — [4]Northeastern University, Boston, USA

Chiral phonons carry angular momentum and lead to magnetic responses in applied magnetic fields or when resonantly driven with ultrashort laser pulses. On the basis of purely circular ionic motion, these phonons are expected to carry a magnetic moment of the order of a few nuclear magnetons. However, some recent experiments have demonstrated a phonon magnetic moment of the order of a few Bohr magnetons. This kind of giant magnetic response points towards the electronic contribution to the magnetic moment of phonons. Many diverse mechanisms have been discovered for this enhanced magnetic response of chiral phonons. The orbital-lattice coupling is one such mechanism where low-energy electronic excitations on a magnetic ion hybridize with phonons and endow a large magnetic moment to phonons. In this talk, I'll present a microscopic model for the effective magnetic moments of chiral phonons based on this mechanism. We apply our model to two types of materials: rare-earth halide paramagnets and transition-metal oxide magnets. In both cases, we find that chiral phonons can carry giant effective magnetic moments of the order of a Bohr magneton, orders of magnitude larger than previous predictions.

MA 5.6 Mon 12:15 H20

Extrinsic Phonon Thermal Hall Effect — •Dimos Chatzichrysafis[1], Robin Richard Neumann[1,2], and Alexander Mook[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Germany

The thermal Hall effect is a developing tool to investigate charge-neutral excitations, exposing the quantum many-body ground state of correlated materials. Since a sense of chirality for the energy carriers is necessary for the generation of a thermal Hall effect, it is natural to expect that quasiparticles of magnetic excitations are responsible for the Hall transport. This conventional wisdom has been recently challenged in experiments [1] which revealed a universal character of the thermal Hall effect independent on the magnetic texture and the lattice structure, even in systems where magnetism is completely absent. This finding asks for the re-investigation of the role of phonons in the thermal Hall effect.

Here, we develop a theory for a phononic thermal Hall effect where the source of chirality is given by the presence of the molecular Berry phase. As a toy model we study a non-magnetic system on a Bravais square lattice. We go beyond the intrinsic mechanism [2] usually studied in literature and consider the contribution of different possible extrinsic sources of phonon Hall transport. Our results demonstrate that phonon thermal Hall effects can be native to very generic systems.

[1] Xiaobo Jin et al, arXiv:2404.02863
[2] Takuma Saito et. al, Phys. Rev. Lett. 123, 255901, December 2019

MA 5.7 Mon 12:30 H20

Signatures of chiral phonons in $MnPS_3$ — •Banhi Chatterjee and Peter Kratzer — Faculty of Physics, University of Duisburg-Essen, Lotharstr. 1, 47057, Duisburg, Germany

Chiral phonons can exist in two-dimensional transition metal dichalcogenide (TMDC) monolayers without inversion symmetry. They can be observed in the non-equilibrium state triggered by optical excitations using circularly polarized light. In existing literature a detailed theoretical calculation of the circular phonons production rate has already been done for the TMDC MoS_2. We investigate the antiferromagnetic semiconductor $MnPS_3$ with a similar hexagonal crystal structure and band-structure like MoS_2 but a larger unit cell as a novel candidate material that may allow for excitation of circular phonons. In $MnPS_3$, although the total magnetic moment is zero in the ground state, exciting the system using circularly polarized light induces a net magnetic moment. The damping of the magnons observed experimentally points to the transfer of orbital angular moment to combined phonon-magnon excitations. Using DFT+U and density functional perturbation theory (DFPT) we obtain in-plane chiral phonon modes at the valley-points of a monolayer $MnPS_3$ and for these modes the S atoms make circular motions. We further study the electron-phonon coupling between these chiral phonon modes and the excited electronic states carrying orbital angular momentum, particularly the dominant d-electrons, in order to theoretically investigate the experimentally observed damping of magnons.

MA 5.8 Mon 12:45 H20

Elliptically polarized coherent phonons in a degenerate mode — Arne Ungeheuer, Mashood T. Mir, Ahmed Hassanien, Lukas Nöding, Thomas Baumert, and •Arne Senftleben — Institut für Physik, Universität Kassel

Controlled excitation of phonons in crystalline solids is an emerging way to alter the property of a material to create phenomena such as transient magnetic polarization [1,2]. Here, we want to focus on controlling the polarization properties of coherent optical phonons that can be launched by ultrashort laser pulses. we demonstrate the excitation of elliptically polarized coherent optical phonons of the E_{2g} shearing mode in graphite. This is achieved by exciting the superposition of two orthogonally polarized phonon modes using a tailored pair of time-delayed optical pulses with tilted polarization. The elliptically polarized coherent phonons are detected by ultrafast electron diffraction [3], where we determine the amount of ellipticity and the sense of rotation.

[1] D. M. Juraschek, et al. *Phys. Rev. Lett.* **118**, 054101 (2017).
[2] A. S. Disa, et al. *Nature Phys.* **16**, 937–941 (2018).
[3] C. Gerbig, et al. *New J. Phys.* **17**, 043050 (2015).

MA 6: Skyrmions I

Time: Monday 15:00–18:30 Location: H16

Invited Talk MA 6.1 Mon 15:00 H16

Magnetization dynamics of chiral helimagnetic insulators — •Aisha Aqeel — University of Augsburg, Augsburg, Germany — Technical University of Munich, Munich, Germany — Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Nature reveals fascinating patterns, often arising from intricate interactions among individual components. In magnets, remarkable patterns can emerge even in the absence of inversion symmetry. Chiral helimagnets, characterized by their twisted magnetic structures, whether topologically trivial or non-trivial, exhibit collective magnetic excitations ranging from GHz to THz. These exceptional properties make helimagnets highly attractive for spintronic technologies and unconventional computing [1]. However, realizing their full potential demands ultraclean magnetic systems with minimal dissipation and a deep understanding of their magnetization dynamics. In this talk, I will delve into the fundamental properties of chiral helimagnets and their dynamic magnetization behavior, focusing on the insulating material Cu2OSeO3. Our studies reveal evidence for a rare magnetic state in Cu2OSeO3 crystals - elongated skyrmions - observed through magnetic resonance experiments [2]. Additionally, utilizing a surface-sensitive electrical probe - spin Hall magnetoresistance - we discovered that the magnetic configurations at the surfaces of chiral magnets deviate significantly from those in the bulk [3].

[1] O. Lee, et al., Nat. Mater. 23(1), 79-87 (2024). [2] A. Aqeel, et al., Phys. Rev. Lett. 126(1), 017202 (2021). [3] A. Aqeel, et al., Phys. Rev. B 103(10), L100410 (2021).

MA 6.2 Mon 15:30 H16

Skyrmion dynamics in Ta/CoFeB/MgO at room temperature — •Hauke Lars Heyen[1], Malte Römer-Stumm[2], Michael Vogel[2], Florian Gossing[2], Jakob Walowski[1], Ethan Andrew Mullen[3], Christian Denker[1], Karin Dahmen[3], Jeffrey McCord[2], and Markus Münzenberg[1] — [1]Institute of Physics, University Greifswald, Germany — [2]Institute of Materials Science, Nanoscale Magnetic Materials and Magnetic Domains, CAU Kiel, Germany — [3]Department of Physics, The Grainger College of Engineering, University of Illinois Urbana-Champaign, USA

Applications in future storage devices, like the conceptual skyrmion race-track memory, require fundamental control over the skyrmion dynamics. We use Ta/CoFeB/MgO layer stacks to generate skyrmions at room temperature. The skyrmions are moved by applying nanosecond electric current pulses with current densities of around $5 \cdot 10^{10} A/m^2$ and are imaged with the magneto optical Kerr effect (MOKE). With a tracking algorithm the trajectories are determined and they hint at two diffusion types and the skyrmion-Hall effect. The latter occurs simultaneously with the topological Hall-effect that can be measured electrically. Combining the electrical measurements with MOKE allows us to separate the anomalous and the weak topological Hall effect. This allows for a differentiation between topological and non-topological stabilized magnetic structures.

MA 6.3 Mon 15:45 H16

Skyrmion Screws: A Novel 3D Topological Spin Texture — •Thorsten Hesjedal[1,2], Gerrit van der Laan[2], Haonan Jin[3,4], Jingyi Chen[3,4], and Shilei Zhang[3,4] — [1]Department of Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, UK — [2]Diamond Light Source, Harwell Science and Innovation Campus, Didcot OX11 0DE, UK — [3]School of Physical Science and Technology, ShanghaiTech University, Shanghai 201210, China — [4]ShanghaiTech Laboratory for Topological Physics, ShanghaiTech University, Shanghai 201210, China

Three-dimensional (3D) magnetic skyrmions have attracted increasing interest as topological spin textures capable of hosting emergent electromagnetic properties and unique spin dynamics. In this study, we present the first direct experimental observation of skyrmion screws — a 3D spin crystal featuring modulations along the z-axis. Using state-of-the-art soft x-ray ptycho-tomography, we fully visualize the skyrmion screw lattice in a $Co_8Zn_{10}Mn_2$ thin lamella, fabricated to induce boundary confinement effects. Ferromagnetic resonance spectroscopy and micromagnetic simulations reveal a distinct low-frequency resonance mode, establishing skyrmion screws as a fundamentally new phase. These findings open avenues for studying 3D topological magnetism and its applications in magnonics and spintronics.

MA 6.4 Mon 16:00 H16

Skyrmion bags embedded in the skyrmion lattice — •Nikolai S. Kiselev — Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany

The micromagnetic model of 2D chiral magnets predicts the existence of skyrmion bags – solitons with arbitrary topological charge [1]. Recent experiments have confirmed the stability of skyrmion bags with positive topological charges [2,3]. Using Lorentz TEM on thin plates of B20-type FeGe, we demonstrate the remarkable stability of skyrmion bags with negative charges embedded within a skyrmion lattice [4]. We outline a robust protocol for nucleating these embedded skyrmion bags, which remain stable even in zero or inverted external magnetic fields. Our findings are in excellent agreement with micromagnetic simulations.

[1] F.N. Rybakov, N.S. Kiselev Phys. Rev. B, 99, 064437 (2019). [2] J. Tang et al., Nature Nanotechnol. 16, 1086 (2021). [3] Y. Zhang et al., Nature Commun. 15, 3391 (2024). [4] L. Yang et al., Adv. Mater. 36, 2403274 (2024).

MA 6.5 Mon 16:15 H16

Skyrmion at finite temperature — •Thorben Pürling[1,2] and Stefan Blügel[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Physics Department, RWTH Aachen University, 52062 Aachen, Germany

In the past decade magnetic skyrmions have been under intense scientific scrutiny. Key properties of magnetic skyrmions such as the radius have been shown to exhibit highly nonlinear behavior as a function of the microscopic interaction parameters representing Heisenberg exchange, Dyzaloshinskii-Moriya interaction (DMI) and magnetic anisotropy [1]. Due to thermal fluctuations in both spin and lattice degrees of freedom, these interaction strengths carry an effective temperature dependence. Hence, temperature should demonstrate a strong effect on quantities like the skyrmion radius. Surprisingly little work has been done in this direction, particularly when it comes to taking lattice vibrations into account. Here we present our first attempts at investigating the role of the lattice dynamics on relevant interaction parameters.

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

[1] H. Jia *et al.*, Phys. Rev. Materials **4**, 094407 (2020).

MA 6.6 Mon 16:30 H16

Skyrmion lattices emerging from magnetic dipolar interactions — Elizabeth M Jefremovas[1], •Kilian Leutner[1], Miriam G. Fischer[1], Jorge Marqués-Marchán[2], Thomas B. Winkler[1], Agustina Asenjo[2], Jairo Sinova[1,3], Robert Frömter[1], and Mathias Kläui[1,4] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Institute of Material Science of Madrid – CSIC, 28049 Madrid, Spain — [3]Department of Physics, Texas A&M University, College Station, Texas, USA — [4]Center for Quantum Spintronics, Norwegian University of Science and Technology, 7491 Trondheim, Norway

Magnetic skyrmions are well-studied two-dimensional topological spin textures. Surprisingly, little is known about the mutual interactions of dipolar-stabilized skyrmions. By engineering a magnetic multilayer stack, we stabilize for 1 to 30 repetitions skyrmion lattices at room temperature and zero field. Using Kerr microscopy and Magnetic Force Microscopy we observe a drastic decrease in skyrmion size as the number of repetitions is increased. We present an analytical model to describe the skyrmion radius and periodicity from the single-layer to the thick-film limit and complement this with micromagnetic simulations. Additionally, we identify the critical role of the nucleation process in forming the skyrmion lattice. Our work provides a comprehensive understanding of skyrmion-skyrmion interactions, which are driven by dipolar interactions as the multi-layer stack thickness increases.

[1] E. M. Jefremovas et al., arXiv:2407.00539 (2024)

15 min. break

MA 6.7 Mon 17:00 H16

Skyrmion size manipulation by external force — Klaus Raab, Kilian Leutner, •Leonie-Charlotte Dany, Simon Fröhlich, Grischa Beneke, Duc Minh Tranh, Sachin Krishnia, Robert Frömter, Peter Virnau, and Mathias Kläui — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Magnetic skyrmions, spin textures with quasi-particle like properties, exhibit highly promising potential as information carriers in applications like storage or non-conventional computing.[1,2]

We experimentally investigate how the size of skyrmions is influenced by a combination of spin-orbit torques and repulsion from a structural barrier in a Ta/CoFeB/MgO based magnetic thin film. By employing Ga^+ ion implantation to modify the effective anisotropy of the magnetic layer, we create artificial barriers that serve as additional tools for manipulating skyrmions. Furthermore, the resulting changes in the formation of skyrmions lattice is characterized.

Based on the experimental finding, we then develop a new theoretical model within the framework of Thiele equation approach to describe the change in the skyrmions' size and their trajectories. Thiele equation accounts for the skyrmion size and skyrmion-skyrmion distance of an ensemble of skyrmions to an external stimulus, such as spin-orbit torques.

1. Raab, K. *et al., Nat. Commun.* **13**, 6982 (2022).
2. Beneke, G. *et al., Nat. Commun.* **15**, 8103 (2024).

MA 6.8 Mon 17:15 H16

Eigenmode following for direct entropy calculation — •Stephan von Malottki[4], Moritz A. Goerzen[1], Hendrik Schrautzer[1,2], Pavel F. Bessarab[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstrasse 15, 24098 Kiel, Germany — [2]cience Institute, University of Iceland, 107 Reykjavík, Iceland — [3]Department of Physics and Electrical Engineering, Linnaeus University, SE-39231 Kalmar, Sweden — [4]MODL, Insititute of Condensed Matter and Nanosciences, UC Louvain, Belgium

We present an eigenmode following method (EMF) to numerically calculate entropy contributions beyond harmonic approximation. In the framework of transition state theory, this increases the accuracy and applicability of transition rate calculations. In EMF, the potential energy landscape is explored along the investigated eigenvectors by iteratively updating a partial Hessian matrix along the way. Numerical integration of the Boltzmann factor over the obtained energy curve yields the contribution of the eigenmode to the partition function and entropy of the analysed state. The EMF method can be combined with other methods such as the harmonic approximation, making it a feasible method to improve the description of individual eigenmodes. The application of the method will be shown on the example of the Chimera skyrmion collapse mechanism and antiskyrmion rotation modes.

MA 6.9 Mon 17:30 H16

Topological magnetism in diluted artificial adatom lattices — •Amal Aldarawsheh[1,2] and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulations, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]aculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

The ability to control matter at the atomic scale has revolutionized our understanding of the physical world, opening doors to unprecedented technological advancements. Quantum technology, which harnesses the unique principles of quantum mechanics, enables us to construct and manipulate atomic structures with extraordinary precision. Here[1], we propose a bottom-up approach to create topological magnetic textures in diluted adatom lattices on the Nb(110) surface. By fine-tuning adatom spacing, previously inaccessible magnetic phases can emerge. Our findings reveal that interactions between magnetic adatoms, mediated by the Nb substrate, foster the formation of unique topological spin textures, such as skyrmions and anti-skyrmions, both ferromagnetic and antiferromagnetic. Since Nb can be superconducting, our findings present a novel platform with valuable insights into the interplay between topological magnetism and superconductivity, paving the way for broader exploration of topological superconductivity in conjunction with spintronics applications.

[1] A. Aldarawsheh et al., In preparation. Work funded by the PGSB (BMBF-01DH16027)and DFG (SPP 2137; LO 1659/8-1)

MA 6.10 Mon 17:45 H16

The impact of magnetic anisotropy on the stability of antiskyrmions in schreibersite magnets — •Mamoun Hemmida[1], Jan Masell[2,3], Kosuke Karube[3], Dieter Ehlers[1], Hans-Albrecht Krug von Nidda[1], Vladimir Tsurkan[1,4], Yoshinori Tokura[3,5,6], Yasujiro Taguchi[3], and Istvan Kezsmarki[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany — [3]RIKEN Center for Emergent Matter Science, Japan — [4]Institute of Applied Physics, Academy of Sciences of Moldova, Republic of Moldova — [5]Department of Applied Physics and Quantum-Phase Electronics Center, University of Tokyo, Japan — [6]Tokyo College, University of Tokyo, Japan

Magnetic anisotropy is a fundamental property of magnetic materials that plays an essential role in the stability of magnetic domains and skyrmions. In this ferromagnetic resonance (FMR) study we report the evolution of magnetic anisotropy by substituting various $4d$ metals in the easy-plane schreibersite magnet $(Fe,Ni)_3P$ with S_4 tetragonal symmetry,Hemmida2024. Starting from easy-plane anisotropy, Pd doping turns $(Fe,Ni)_3P$ to an easy-axis-type magnet. As a consequence, antiskyrmions are created. FMR study of the planar anisotropy proofs a fourfold symmetry as expected for the tetragonal crystal structure. The corresponding planar anisotropy parameter is an order of magnitude smaller than the uniaxial one. Hemmida2024 M. Hemmida, *et al.*, Phys. Rev. B 110, 054416 (2024).

MA 6.11 Mon 18:00 H16

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

The Heusler compound $Mn_{1.4}PtSn$ is a chiral magnet that exhibits a rich of variety non-topological and topologically protected chiral magnetic textures at room temperature. We have used Lorentz transmission electron microscopy (LTEM) supported by resonant elastic x-ray scattering (REXS) and micromagnetic simulations to characterize the emerging magnetic structures as function of the magnitude and orientation of an external magnetic field. We find that in out-of-plane fields, chiral soliton lattices emerge, while in-plane fields promote the formation of non-chiral magnetic fan domains. At fields in the stability range of the latter, the nucleation of non-topological bubbles (ntB's) occurs. Intriguingly, ntB's show combined characteristics of chiral solitons and the fan-type structure and may consequently be interpreted as hybrid structures of the latter. Following a distinct field protocol, ordered lattices of these ntB's then successively transform into anti-skyrmion lattices. Financial support by DFG through SPP 2137, project no. 403503416, is gratefully acknowledged.

MA 6.12 Mon 18:15 H16

Emergence of polar skyrmions in 2D Janus CrInX3 (X=Se, Te) magnets — •Duo Wang[1], Fengyi Zhou[1], Monirul Shaikh[2], and Biplab Sanyal[3] — [1]Macao Polytechnic University — [2]University of Nebraska, Kearney — [3]Uppsala University

In the realm of multiferroicity in 2D magnets, whether magnetic and polar skyrmions can coexist within a single topological entity has emerged as an important question. Here, we study Janus 2D magnets CrInX3 (X=Se, Te) for a comprehensive investigation of the magnetic ground state, magnetic excited state, and corresponding ferroelectric polarization by first-principles electronic structure calculations and Monte Carlo simulations. Specifically, we have thoroughly elucidated the magnetic exchange mechanisms, and have fully exemplified the magnetic field dependence of the magnon spectrum. More importantly, our study reveals a previously unrecognized, remarkably large spin-spiral-induced ferroelectric polarization (up to 194.9 μC/m2) in both compounds. We propose an approach to identify polar skyrmions within magnetic skyrmions, based on the observed direct correlation between spin texture and polarization density. Elucidating this correlation not only deepens our understanding of magnetic skyrmions but also paves the way for innovative research in the realm of multiferroic skyrmions.

MA 7: INNOMAG e.V. Prizes 2025 (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 2025 in Regensburg 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 2025. Talks will be given in English!

Time: Monday 15:00–18:00 Location: H18

Invited Talk MA 7.1 Mon 15:00 H18

Realizing Reservoir Computing with skyrmions in geometrical confinements tuned by ion irradiation — •Grischa Beneke — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany

Physical reservoir computing (RC) is a beyond von-Neumann computing paradigm that harnesses complex physical systems' dynamics for efficient information processing. Magnetic skyrmions, topological spin textures, show promise for RC systems due to their non-linear interactions and low-power manipulation capabilities. Previous spin-based RC implementations either focused on static detection or required rescaling of real-world data to match intrinsic magnetization dynamics timescales. In this thesis, we demonstrate time-multiplexed skyrmion RC by adjusting the reservoir's intrinsic timescales to match real-world temporal patterns [1]. Using hand gestures recorded via range-Doppler radar in collaboration with industry, we show that our hardware solution outperforms conventional software-based neural networks while consuming less energy. The system's ability to directly integrate sensor data without temporal conversion enables real-time applications. To structure the geometrical confinement, we investigate how high-energy ion irradiation influences magnetic properties in skyrmion-hosting multilayers. By locally modifying the perpendicular magnetic anisotropy, we create attractive and repulsive regions that enable controlled skyrmion nucleation, manipulation and confinement, enabling novel devices and, enhancing device functionality. [1] G. Beneke et al., Nat. Commun. 15, 8103 (2024).

Invited Talk MA 7.2 Mon 15:20 H18

Low-energy spin excitations of the Kitaev candidate material $Na_2Co_2TeO_6$ probed by high-field/high-frequency electron spin resonance spectroscopy — •Luca Bischof[1], Jan Arneth[1], Kwang-Yong Choi[2], Raju Kalaivanan[3], Raman Sankar[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, Sungkyunkwan University, Republic of Korea — [3]Institute of Physics, Academia Sinica, Taiwan

The realization of a Kitaev spin liquid state in the Co-based honeycomb magnet $Na_2Co_2TeO_6$ is circumvented by magnetic ordering due to Heisenberg and off-diagonal interactions. The nature of these interactions and the magnetic ground state in $Na_2Co_2TeO_6$ are still under debate. We report high-frequency/high-field electron spin resonance (ESR) measurements of single-crystal $Na_2Co_2TeO_6$ probing the low-energy spin excitations of the ordered phase below $T_N \simeq 27\,K$. A complex magnon spectrum for in-plane magnetic fields $B \parallel a^*$ indicates field-induced phase transitions. For out-of-plane magnetic fields $B \parallel c$, we observe one softening and two hardening magnon modes. They share a magnon excitation gap of $\Delta = 219(13)\,GHz$. We performed spin wave calculations for the extended Heisenberg-Kitaev model to compare the observed magnon modes to the low-energy excitations expected for zigzag and triple-q ground states in an applied magnetic field.

Invited Talk MA 7.3 Mon 15:40 H18

Tailoring the first-order magnetostructural phase transition in Ni-Mn-Sn for caloric applications by microstructure — •Johannes Puy, Enrico Bruder, Oliver Gutfleisch, and Franziska Scheibel — TU Darmstadt, Darmstadt, Germany

Ni-Mn-Sn Heusler alloys show a large inverse magnetocaloric (MCE) and conventional elastocaloric effect (ECE), making them a promising candidate for multicaloric cooling. The caloric effects arise from a first-order magnetostructural phase transition (FOMST) from high-magnetic austenite to low-magnetic martensite, driven by a nucleation and growth process. Optimizing the multicaloric performance of these materials requires tailoring the FOMST, which implies a comprehensive understanding of the role of microstructure and coupling factors, such as atomic, magnetostatic, and stress coupling. In this study, the influence of microstructure and defects (grain boundaries, pores, sintering necks) on the temperature-driven FOMST is investigated in single- and polycrystalline particles, as well as in spark-plasma-sintered Ni-Mn-Sn. By adjusting the relative density, the effect of porosity on the FOMST is studied. Temperature-dependent magnetometry reveals that an increase of the relative density from 88 % to 99 % narrows the transition ranges from 18 K to 9 K and decreases the transition temperature from 263 K to 254 K. Temperature-dependent in-situ optical and in-situ scanning electron microscopy reveal preferential martensite nucleation at free particle surfaces in powder and sintered, 88% dense Ni-Mn-Sn, while nucleation in 99 % dense Ni-Mn-Sn is favored at sintering necks. We thank the CRC/TRR 270 'HoMMage' for funding.

15 min. break

Invited Talk MA 7.4 Mon 16:15 H18

Tuning the properties of two-dimensional magnetic heterostructures via interface engineering with molecular and inorganic van der Waals crystals. — •Carla Boix-Constant[1], Samuel Mañas-Valero[2], and Eugenio Coronado[1] — [1]Institute of Molecular Science, 46980 Paterna (Valencia), Spain. — [2]Kavli Institute of Nanoscience - TU Delft, Delft 2628 CJ, The Netherlands.

Two-dimensional (2D) materials offer unprecedented opportunities for fundamental and applied research in several condensed matter physics areas. For this purpose, state-of-the-art techniques were employed in this thesis (divided in two blocks) to fabricate van der Waals heterostructures based on mainly 2D magnets (both inorganic and molecular systems) and to characterize the resulting devices by magneto-transport techniques. On the one hand, new chemically designed molecular building blocks were combined with 2D materials to afford hybrid devices offering a new playground for exploiting the potential of spin transition molecular systems to control the properties of the 2D material. On the other hand, we focused on purely 2D magnetic materials: the quantum spin liquid candidate 1T-TaS2 - where our results throw some light in the debate about the exotic behaviour of the material - and the metamagnet CrSBr - results that afford a new generation of van der Waals heterostructures with programmable properties.

Invited Talk MA 7.5 Mon 16:40 H18

Theoretical Prediction for Probing Magnon Topology — •Robin R. Neumann — Johannes Gutenberg University Mainz — Martin Luther University Halle-Wittenberg

Magnons, the bosonic quasiparticles of collective spin excitations, hold potential as information and energy carriers in spintronic devices. Although the magnonic counterpart of the electronic quantum Hall states was predicted over a decade ago [1, 2], experimental evidence remains absent because established methods fail to probe them [3].

In my thesis I have studied the signatures of topological magnons in transport and spectroscopic observables. While I demonstrated that the thermal Hall effect can be sensitive to topological phase transitions in the magnon band structure [4], magnon-phonon hybridization may obscure their contributions [5]. I present a specific proposal for using electrical probes to detect topological magnons [6]. Despite their charge neutrality, magnetoelectric effects grant magnons an electrical dipole moment. Consequently, edge magnons give rise to an electric polarization at the edges driven by thermal spin fluctuations. Furthermore, magnons are predicted to interact with alternating electric fields, opening up the possibility of resonantly exciting topological magnons. The resulting absorption spectrum encodes footprints of topological magnons that might assist in their detection.

[1] Zhang *et al.*, PRB **87**, 144101 (2013), [2] Shindou *et al.*, PRB **87**, 174427 (2013), [3] Malz *et al.*, Nat. Commun. **10**, 3937 (2019), [4] **RRN** *et al.*, PRL **128**, 117201 (2022), [5] **RRN** *et al.*, PRB **108**, L140402 (2023), [6] **RRN** *et al.*, PRB **109**, L180412 (2024)

Invited Talk MA 7.6 Mon 17:05 H18

Multiphysics-Multiscale Simulation of Additively Manufactured Functional Materials — •Yangyiwei Yang — Technische Universität Darmstadt, Darmstadt, Germany

The progress of additive manufacturing (AM) technologies has led to a growing interest in AM-produced magnetic functional materials with tailored properties, including magnetic coercivity, remanence and saturation magnetization. However, the lack of comprehensive research on the process-microstructure-property (PMP) relationship poses a significant challenge to the production of magnetic materials with designed properties by AM. In this work, a multiphysics-multiscale simulation framework has been developed to thoroughly investigate the PMP relationships in magnetic functional materials and to further facilitate simulation-driven property tailoring. The framework is methodically structured to ensure clarity and depth, with emphasis on key concepts with corresponding physical backgrounds. By employing the established framework, phenomenological relationships between AM processing parameters and the resulting material properties are obtained, notably magnetic hysteresis. The sensitivity of the local magnetic coercivity to residual stress states in AM-produced Fe-Ni permalloy is also revealed. In particular, the relationship between the average residual stress and the magnetic coercivity within the melt zone are shown to obey an exponential growth law, suggesting a strategy for tailoring the magnetic coercivity by controlling the residual stress within an AM-produced permalloy.

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

MA 8: Spin-Dependent Phenomena in 2D (joint session MA/HL)

Time: Monday 15:00–17:15 Location: H19

MA 8.1 Mon 15:00 H19

Magnetoelectric behavior of breathing kagomé monolayers of Nb3(Cl,Br,I)8 from first-principles calculations — •John Mangeri — Technical University of Denmark, Kongens Lyngby, Denmark

We apply density functional theory to explore the magnetoelectric (ME) properties of two-dimensional Nb3(Cl,Br,I)8. These compounds have recently been proposed to exhibit coupled ferroelectric and ferromagnetic order leading to a switchable anomalous valley Hall effect (AVHE). Using both spin-spiral and self-consistent spin-orbit coupled calculations, we predict an in-plane 120 degree cycloid of trimerized spins as the ground state for Nb3Cl8. For Nb3Br8 and Nb3I8 we find long period incommensurate helical order. We calculate a number of magnetic properties such as the exchange constants, orbital magnetization, and Weiss temperatures. It is then shown that, despite having both broken inversion and time-reversal symmetry, the proposed AVHE and linear ME response are forbidden by the presence of helical order in the ground state. In addition, the computed switching trajectory demonstrates that it is unlikely that the polar state of the monolayers can be switched with a homogeneous electric field due to an unusual equation of state of the out-of-plane dipole moment. Nevertheless, we highlight that in the presence of a strong electric field, the trimerized spins in Nb3Cl8 will exhibit a magnetic phase transition from the 120 degree cycloid to out-of-plane ferromagnetic order, which restores the symmetry required for both AVHE and linear ME effects.

MA 8.2 Mon 15:15 H19

Ab-initio Investigation of two-dimensional Fe-Sn Kagome lattice with Nb doping — •Gérald Kämmerer[1,2] and Sinéad Griffin[2] — [1]Faculty of Physics, University of Duisburg-Essen — [2]Lawrence Berkeley National Laboratory (LBNL), Berkeley

This research investigates Fe-Sn-based kagome compounds for green energy applications, focusing on their magnetic and electronic properties, particularly in spintronics and phononics. We are investigating tunable properties in Fe_3Sn. We aim to control spin states in 2D magnetic systems by studying doped variants (Nb) in Kagome lattices to uncover topological electronic states, including Dirac fermions and flat bands.

Using first-principles calculations, we analyse impurity interactions in 2D lattices using VASP. By comparing experimental data with our computational results, this study aims to provide insights into dopant-controlled quantum states and improve material performance in electronic applications.

The financial support of the DFG within the SFB 1242 and the computational time on the LBNL supercomputer system are gratefully acknowledged.

MA 8.3 Mon 15:30 H19

Spin polarization of the two-dimensional electron gas at the EuO/$SrTiO_3$ interface — •Paul Rosenberger[1,2], Andri Darmawan[3], Olena Fedchenko[1], Olena Tkach[1], Serhii V. Chernov[4], Dmitro Kutnyakhov[4], Moritz Hoesch[4], Markus Scholz[4], Kai Rossnagel[4,5], Rossitza Pentcheva[3], Gerd Schönhense[1], Hans-Joachim Elmers[1], and Martina Müller[2] — [1]JGU Mainz, Germany — [2]Uni Konstanz, Germany — [3]UDE, Duisburg, Germany — [4]DESY, Hamburg, Germany — [5]CAU Kiel, Germany

Spin-polarized two-dimensional electron gases (2DEGs) are of particular interest for functional oxide electronics applications. Here, we use magnetic circular dichroism in the angular distribution (MCDAD) of photoemitted electrons to investigate whether and how the induced spin polarization of the redox-created 2DEG at the EuO/$SrTiO_3$ (001) interface depends on the dimensionality of the strongly ferromagnetic ($7\,\mu_B/f.u.$) EuO layer [1]. Samples with EuO thicknesses ranging from one to four monolayers were studied. We show that the EuO/STO interfacial 2DEG becomes spin-polarized starting from a threshold EuO thickness of only two monolayers. Experimental data are complemented by DFT+U calculations. Our results, and the potential to enhance the magnetic order of EuO by other proximity effects [2], indicate that the EuO/STO interface is an ideal template for creating functional spin-polarized 2DEGs for application in oxide electronics.

[1] Rosenberger *et al.*, arXiv:2410.23804 (2024).
[2] Rosenberger *et al.*, Sci. Rep. **14**, 21586 (2024).

MA 8.4 Mon 15:45 H19

***Ab initio* calculation of Spin-Orbit torques in 2D magnets** — •Gusthavo Brizolla and Jaroslav Fabian — Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

The interplay of spin-orbit coupling and magnetism in two-dimensional materials and their heterostructures presents exciting opportunities for advancing next-generation spintronic devices. In this work, we investigate the role of proximity effects in generating spin-orbit torques (SOTs) in Fe_3GeTe_2 (FGT) and FGT-based van der Waals heterostructures. Using a tight-binding Hamiltonian derived from first-principles calculations via the Wannierization procedure, we evaluate the torkances within the linear response regime using the Kubo formalism. Our results reveal key mechanisms underlying the generation of torques driven by spin accumulation, elucidating the fundamental physics of SOTs in these systems.

This research has been supported by 2D SPIN-TECH.

MA 8.5 Mon 16:00 H19

Unveiling Long-range Magnetic Textures in Twisted Moiré Antiferromagnets — •King Cho Wong[1], Ruoming Peng[1], Xiaodong Xu[3], Elton Santo[2], Adam Wei Tsen[4], Rainer Stoehr[1], and Joerg Wrachtrup[1] — [1]3rd Physics Institute, University of Stuttgart, Stuttgart, Germany — [2]University of Edinburgh, United Kingdom — [3]University of Washington, USA — [4]University of Waterloo, Canada

Stacking two-dimensional (2D) materials offers a controllable and versatile platform to engineer interlayer interactions, unveiling numerous intriguing correlated and topological states. Recent progresses in twisted 2D magnets have revealed periodic ferromagnetic domains due to the local Moiré stacking. In this study, we employed scanning quantum microscopy to investigate local magnetic responses of twisted double bilayer chromium triiodide (tDB CrI3). We observed unexpected antiferromagnetic textures with periods more than 300 nm at the 1.1° twisted devices, which are significantly exceeding the corresponded Moiré size of about 30 nm. These periodic magnetic textures are setting atop randomly distributed ferromagnetic domains with net two-layer magnetization of 30 uB/nm^2 and antiferromagnetic domains with magnetization of 0 uB/nm^2. Our findings suggest that strong magnetic competition at small twisted angles (<2°) can extend magnetic textures beyond the Moiré size, leading to the emergence of Néel skyrmions after field cooling.

MA 8.6 Mon 16:15 H19

Spin model of graphene triangulenes embedded in hexagonal boron nitride — •Dániel Tibor Pozsár[1,3,4,5], László Oroszlány[1,2,3], and Viktor Ivády[1,4,5,6] — [1]Department of Physics of Complex Systems, Eötvös Loránd University, Egyetem tér 1-3, H-1053 Budapest, Hungary — [2]Wigner Research Centre for Physics, Konkoly-Thege M. út 29-33, H-1121 Budapest, Hungary — [3]TRILMAX Consortium, Twinning, Horizon Europe, Budapest, Hungary — [4]QUEST projec, Twinning, Horizon Europe, Budapest, Hungary — [5]MTA*ELTE Lendület "Momentum" NewQubit Research Group, Pázmány Péter, Sétány 1/A, 1117 Budapest, Hungary — [6]Department of Physics, Chemistry and Biology, Linköping University, SE-581 83 Linköping, Sweden

We are investigating triangulene shaped substitutional defects in hexagonal boron nitride filled with carbon atoms. We show how the triangulene shaped defects encompass magnetic moments and with ab initio methods we build Heisenberg like classical spin models representing their interactions. We show how different lattice terminations and sizes impact the magnetic properties of the system.

MA 8.7 Mon 16:30 H19

Realizing Spin-3/2 AKLT State for Quantum Computation with Tetrapod Architectures — •Claire Benjamin[1], László Oroszlány[1,2], Dániel Varjas[3], and Gábor Széchenyi[1] — [1]Department of Physics of Complex Systems, Eötvös University, Pázmány Péter sétány 1/A, H-1117 Budapest, Hungary — [2]Wigner Research Centre for Physics, Konkoly-Thege M. út 29-33, H-1121 Budapest, Hungary — [3]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary

Using a novel tetrapod (5-site cluster) architecture, we implement spin-3/2 degrees of freedom in a semiconductor quantum bit platform. This framework enables us to construct a tunable artificial spin system that can realize the two-dimensional Affleck-Kennedy-Lieb-Tasaki (AKLT) state on a honeycomb lattice, known to be a universal resource for measurement-based quantum computation. We assess the model's robustness and feasibility for measurement based quantum computing using semi-analytic perturbation theory and numerical calculations.

MA 8.8 Mon 16:45 H19

Anomalous quantum oscillations from boson-mediated interband scattering — •Léo Mangeolle[1,2] and Johannes Knolle[1,2,3] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

Quantum oscillations (QO) in metals refer to the periodic variation of thermodynamic and transport properties as a function of inverse applied magnetic field. QO frequencies are normally associated with semi-classical trajectories of Fermi surface orbits but recent experiments challenge the canonical description. We develop a theory of composite frequency quantum oscillations (CFQO) in two-dimensional Fermi liquids with several Fermi surfaces and interband scattering mediated by a dynamical boson, e.g. phonons or spin fluctuations. Specifically, we show that CFQO arise from oscillations in the fermionic self-energy with anomalous frequency splitting and distinct strongly non-Lifshitz-Kosevich temperature dependencies. Our theory goes beyond the framework of semi-classical Fermi surface trajectories highlighting the role of many-body effects. We provide experimental predictions and discuss the effect of non-equilibrium boson occupation in driven systems.

MA 8.9 Mon 17:00 H19

Identifying the Origin of Thermal Modulation of Exchange Bias in $Fe_3GeTe_2/MnPS_3$ van der Waals Heterostructures — Aravind Puthirath Balan[1], •Aditya Kumar[1], Patrick Reiser[2], Joseph Vimal Vas[3], Thibaud Denneulin[3], Rafal E. Dunin-Borkowski[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

This study investigates the origin of exchange bias in $Fe_3GeTe_2/MnPS_3$ vdW heterostructures. A substantial 170 mT exchange bias is observed at 5 K, one of the largest values reported for vdW heterostructures, despite the compensated interfacial spin configuration of $MnPS_3$. This exchange bias is linked to unexpected weak ferromagnetic ordering in $MnPS_3$ below 40 K that we reveal by NV center imaging. A 1000% variation in the magnitude of exchange bias is obtained through thermal cycling linked to changes in the vdW gap during field cooling. Detailed interface analysis reveals atom migration between layers, forming amorphous regions on either side of the vdW gap. These findings underscore the robust and tunable nature of exchange bias in vdW heterostructures but also challenge the often assumed pristine nature of vdW interfaces calling for in-depth interface characterization.

[1] A. P. Balan et al., Advanced Materials 36, 2403685 (2024).

MA 9: Altermagnets I

Time: Monday 15:00–18:30 Location: H20

MA 9.1 Mon 15:00 H20

Tuning the Octupolar Degrees of Freedom in the Altermagnetic Candidate MnF_2 by Strain and Magnetic Field — •Rahel Ohlendorf[1,2], Hilary M. L. Noad[1], Jörg Schmalian[3], Elena Hassinger[2], Andrew P. Mackenzie[1,4], and Elena Gati[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [2]Technical University, Dresden, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]University of St Andrews, UK

Altermagnetism can unambiguously be differentiated from the known ferro- and antiferromagnetic phases within the framework of spin-group symmetry [1]. In centrosymmetric altermagnets the ordered state can be described in terms of ferroically ordered magnetic octupoles [2]. The experimental conjugate field that is predicted to couple to this order parameter is a combination of strain and magnetic field. Consequently the application of strain and magnetic field should enable the exploration of the physics near the ferrooctupolar critical point, including its associated crossover lines.

We discuss experimental phase diagrams on the centrosymmetric altermagnetic candidate MnF_2 in magnetic field and strain, mapped out by means of elastocaloric measurements and compare our results to theoretical predictions based on a Landau free energy [3].

[1]L. Smejkal et al., Phys. Rev. X 12, 031042 (2022)
[2]S. Bhowal et al., Phys. Rev. X 14, 011019 (2024)
[3]P. McClarty et al., Phys. Rev Lett. 132, 176702 (2024)
*Work is supported by the DFG through TRR288 (Elasto-Q-Mat).

MA 9.2 Mon 15:15 H20

Tuning the magnetic anisotropy of the altermagnet CrSb — •Miriam Fischer[1], Lukas Odenbreit[1], Sonka Reimers[1], Toni Helm[2], Mathias Kläui[1], and Martin Jourdan[1] — [1]Johannes Gutenberg Universität, Mainz — [2]Helmholtz-Zentrum Dresden-Rossendorf

CrSb is an altermagnetic compound, whose band structure we recently investigated by SX-ARPES [Rei24]. For the utilization of this compound in spintronics, a rotation of the magnetic easy axis is required. Thus, we study the tunability of the magnetic anisotropy of CrSb and related compounds by measurements of the spin-flop field.

[Rei24] S. Reimers et al., Nat Commun. 15, 2116 (2024)

MA 9.3 Mon 15:30 H20

Local signatures of altermagnetic order — •Jannik Gondolf[1], Andreas Kreisel[1], Mercè Roig[1], Daniel F. Agterberg[2], and Brian M. Andersen[1] — [1]Niels Bohr Institute, University of Copenhagen, DK-2200 Copenhagen, Denmark — [2]Department of Physics, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201, USA

Altermagnets are known to share properties of ferromagnets and antiferromagnets. They feature time-reversal symmetry breaking, non-relativistic anisotropic band splitting and compensated net magnetization. Fundamental properties of altermagnetism include the anomalous Hall effect, a spin-polarized band structure in angle-resolved photoemission spectroscopy and spin-polarized currents. We employ a minimal model to investigate the local signatures of altermagnetism in the vicinity of impurities using T-matrix theory and exact diagonalization. Our findings suggest that the altermagnetic symmetry breaking is directly imprinted in the local density of states. These signatures can be quantified by scanning tunnel microscopy, offering a new approach for identifying and characterizing potential altermagnetic materials experimentally. Further, we explore potential interplay between altermagnetism and superconductivity.

MA 9.4 Mon 15:45 H20

Spin-wave theory and magnon transport properties of altermagnetic hematite (α-Fe2O3) — •Rhea Hoyer[1], P. Peter Stavropoulos[2], Libor Šmejkal[1,3,4], and Alexander Mook[1] — [1]Department of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Nothnitzer Str. 38, 01187 Dresden, Germany — [4]Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

We develop a four-sublattice spin-wave theory for the g-wave altermagnet hematite (α-Fe2O3) in its two magnetic phases: the easy-axis phase below, and the weak ferromagnetic phase above the Morin temperature. We estimate the Morin temperature with a free energy calculation. The relativistic magnon dispersion relation in the easy-axis phase shows the spin (or chirality) splitting typical of altermagnets. We investigate magnon transport properties with a particular focus on the crystal thermal Hall effect.

MA 9.5 Mon 16:00 H20

Giant spatial anisotropy of magnon lifetime in altermagnets — •António Costa[1,2], João Henriques[1,3], and Joaquín Fernández-Rossier[1] — [1]International Iberian Nanotechnology Laboratory, Braga, Portugal — [2]Physics Center of Minho and Porto Universities (CF-UM-UP), Braga, Portugal — [3]Universidade de Santiago de Compostela, Santiago de Compostela, Spain

Altermagnets are a new class of magnetic materials with zero net magnetization (like antiferromagnets) but spin-split electronic bands (like ferromagnets) over a fraction of reciprocal space. As in antiferromagnets, magnons in altermagnets come in two flavours, that either add one or remove one unit of spin to the $S = 0$ ground state. However, in altermagnets these two magnon modes are non-degenerate along some directions in reciprocal space. Here we show that the lifetime of altermagnetic magnons has a very strong dependence on both flavour and direction. Strikingly, coupling to Stoner modes leads to a complete suppression of magnon propagation along selected spatial directions. This giant anisotropy will impact electronic, spin, and energy transport properties and may be exploited in spintronic applications.

MA 9.6 Mon 16:15 H20

Chiral spin-flip magnons in metallic altermagnets from many-body perturbation theory — •Wejdan Beida[1], Ersoy Sasioglu[2], Gustav Bihlmayer[1], Christoph Friedrich[1], Yuiry Mokrousov[1], Ingrid Mertig[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany

Altermagnets represent a novel class of magnetic materials that bridge the gap between conventional ferro- and antiferromagnets. A unique feature of altermagnets is the lifting of degeneracy of their spin-wave modes (magnons) along the same crystallographic directions in which electronic bands also exhibit spin splitting. This non-degeneracy leads to chirality and directional anisotropy in spin-wave dispersions. In this presentation, we present the spin splitting of electronic bands and chiral spin-wave excitations in a series of metallic altermagnets, which have NiAs-type crystal structure, using DFT and many-body perturbation theory [1]. Our findings reveal a pronounced anisotropic splitting in chiral magnon bands, a small chiral asymmetry in the magnon lifetime, and demonstrate that magnon damping due to Stoner excitations is minimal. This results in long-lived magnons with efficient propagation, underscoring the potential of altermagnets for advanced spintronic and magnonic applications.

W.B. acknowledges support by the Palestinian-German Science Bridge.

[1] E. Sasioglu et al., Phys. Rev. B 81,054434 (2010).

MA 9.7 Mon 16:30 H20

Fingerprints of altermagnetism in the optical properties of MnTe — •Luca Felipe Haag[1], Marius Weber[1,2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, Germany

It has recently been demonstrated by magneto-optical Kerr effect (MOKE) measurements that the spin system in planar d-wave altermagnets can be controlled by linearly polarized optical excitation [2] as one can selectively address spin-up or spin-down electrons by choosing the polarization of the optical pulse. The objective of this study is to investigate whether similar optical effects can be observed in bulk g-wave altermagnets. To this end, we focus on MnTe, which has been demonstrated to be altermagnetic by ARPES measurements [3]. Using ab-initio techniques together with a time-dependent calculation of the

absorption process, we study theoretically the optically induced spin polarization for all polarization angles. Our results show an intriguing interplay between the complex nodal-plane structure in bulk g-wave altermagnets and the anisotropic excitation due to the polarized pulses, causing planar d-wave or g-wave signatures depending on the laser's incident direction.

References: [1] L. Šmejkal et al., Phys. Rev. X 12, 040501 (2022) [2] M. Weber et al., arXiv:2408.05187 (2024) [3] Krempaský et al., Nature 626, 517-522 (2024)

15 min. break

MA 9.8 Mon 17:00 H20

Optical Excitation of Spin Polarization in the Altermagnet RuO_2 — •Marius Weber[1], Stephan Wust[1], Luca Haag[1], Akashdeep Akashdeep[2], 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], Benjamin Stadtmüller[5], and Hans Christian Schneider[1] — [1]University of Kaiserslautern-Landau, Germany — [2]Johannes Gutenberg University Mainz, Germany — [3]CIQUS, Universidade de Santiago de Compostela, Spain — [4]The University of Tokyo, Japan — [5]Augsburg University, Germany

We explore the ultrafast response of altermagnetic materials after optical excitation with femtosecond light pulses. For the case of RuO_2, we employ ab-initio based dynamical calculations to predict the spin polarization of the optically excited carriers. Our theoretical results are confirmed by time-resolved MOKE experiments[1], which demonstrate that highly spin-polarized carrier distributions can be generated in ultrathin, strained RuO_2 by tuning the excitation conditions, in particular the orientation of the light polarization vector.

[1] M. Weber et al., arXiv:2408.05187 (2024)

MA 9.9 Mon 17:15 H20

Magnetotransport in altermagnetic CrSb — •Christoph Müller — FZU Prague

Altermagnets (AMs) constitute a recently established category of magnetically ordered materials distinguished by an antiparallel alignment of identical magnetic moments, however with an alternating spin polarization in the electronic band structure. This unique attribute has ignited considerable interest in exploring novel applications within the realm of spintronics. Furthermore, AMs host transport and optical effects, associated with spin-polarized currents and strongly spin-split bands otherwise only observed in ferromagnets. Chromium Antimonide (CrSb) is due to its crystal symmetry and its compensated order classified as an altermagnet. CrSb exhibits a sizable spin splitting of 1.2 eV which is enabled by the non-relativistic crystal field origin. In my work I investigated the magnetotransport properties of the material in bulk and thin films. The bulk samples were also measured in a high field laboratory in search for a spin-flop transition or the anomalous Hall effect.

MA 9.10 Mon 17:30 H20

Altermagnetic spin wave dispersion in atomistic spin models — •Tobias Dannegger[1], Levente Rózsa[2,3], László Szunyogh[3], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, Konstanz, Germany — [2]Department of Theoretical Solid State Physics, Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [3]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

Altermagnets have a broken symmetry reflected in the shape of the spin density around the magnetic atoms. Using an ab initio parametrised atomistic spin model of hematite (α-Fe_2O_3), we show that this altermagnetic symmetry breaking induces a remarkably high splitting of 2.8 meV in the isotropic exchange couplings between the Fe spins for equidistant neighbours within the thirteenth coordination shell. We further study the resulting spin-wave dispersion relation and find that, in addition to the relativistic band splitting on the order of 10 GHz present almost throughout the entire Brillouin zone, the altermagnetic asymmetry of the isotropic interactions causes a much larger band splitting of the order of 1 THz, but only along low-symmetry directions in the Brillouin zone.

MA 9.11 Mon 17:45 H20

First-principles calculations of Luttinger ferrimagnets — •Jan Priessnitz[1], Igor Mazin[2], and Libor Šmejkal[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Department of Physics and Astronomy, and Quantum Science and Engineering Center, George Mason University, Fairfax, VA, USA

The discovery of altermagnets demonstrated that it is possible to have a material with zero net magnetization, but broken Kramers' spin degeneracy and large spin-splitting, even without considering relativistic effects (spin-orbit coupling) [1]. The altermagnetic spin polarization promises applications in the field of spintronics.

Apart from altermagnets, there are several other classes of magnets showing such properties, such as the Luttinger compensated ferrimagnets. These are materials containing two or more magnetic sublattices which are not connected by symmetry, but which perfectly compensate each other by the virtue of Luttinger's theorem [2].

In this talk, we will give a brief introduction into Luttinger compensated ferrimagnets and present first-principle calculations of several candidate materials and unconventional properties not seen in conventional magnetic materials.

[1] Šmejkal, L., Sinova, J., & Jungwirth, T. (2022). Physical Review X, 12(3).

[2] Mazin, I. (2022). Editorial, Physical Review X, 12(4).

MA 9.12 Mon 18:00 H20

Magnetic domain features in the altermagnetic Mn_5Si_3 — •Gregor Skobjin[1], Javier Rial[2], Sebastian Beckert[3], Helena Reichlová[3,4], Andy Thomas[3,5], Vincent Baltz[2], Lisa Michez[6], Richard Schlitz[1], Michaela Lammel[1], and Sebastian T.B. Goennenwein[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Université Grenoble Alpes, CNRS, CEA, IRIG-Spintec, France — [3]IFMP, TU Dresden, Germany — [4]Institute of Physics ASCR, Czech Republic — [5]Aix-Marseille Université, CNRS, CINaM, France — [6]IFW Dresden, Germany

Altermagnets are an intriguing novel class of magnetic materials. We exploit the anomalous Hall effect response of micropatterned Mn_5Si_3 thin films to investigate their magnetization relaxation behavior. In experiments at $T < 200\,K$ i.e., in the altermagnetic phase, and for magnetic fields for which the samples exhibit large magnetic susceptibility, we observe a strong magnetic aftereffect as well as Barkhausen-like steps in the time-dependent Hall voltage evolution. More specifically, we recorded the evolution of the Hall voltage in micropatterned Hall bars with widths of 10 microns down to 0.1 microns at a series of different magnetic field magnitudes to gain insights into potential domain effects in the altermagnetic phase of Mn_5Si_3. We critically analyze our experimental results and discuss implications for the micromagnetic structure of altermagnetic thin films.

MA 9.13 Mon 18:15 H20

Altermagnetism in twisted magnetic bilayers — •Venkata Krishna Bharadwaj[1], Libor Šmejkal[1,2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

A recent development in the field of magnetism has introduced a new category of magnetic materials known as altermagnets [1]. These materials form a distinct class of magnetic compounds, characterized by magnetic compensation and the breaking of time-reversal symmetry, leading to a spin-split band structure. This unique band structure exhibits alternating spin polarization in both real and reciprocal spaces. The spin splitting originates from variations in local crystal field anisotropies across different magnetic sublattices. In this study, we introduce a novel approach to achieve altermagnetism in two-dimensional van der Waals materials by twisting bilayers. Furthermore, we explore the physical properties of altermagnets arising in these twisted bilayer structures. Our results lay the groundwork for exploring new possibilities in altermagnetic materials.

[1] L. Šmejkal, et al., Phys. Rev. X 12, 031042 (2022).

MA 10: Focus Session: Magnetic Phenomena from Phonon Chirality and Angular Momentum II (joint session MA/TT)

The magnetic moment of the electron lies at the heart of magnetism and spintronics. However, recent research has unveiled the angular momentum and magnetic moment of chiral phonons as fundamental quantities in their own right. These chiral phonons give rise to a plethora of novel lattice phenomena analogous to electronic effects, such as the phonon Hall and phonon Zeeman effects. Moreover, they play a critical role in angular momentum transfer on ultrafast timescales, as seen in the Einstein-de Haas effect. Chiral phonons can also generate effective magnetic fields reaching the tesla scale, inducing magnetization in antiferromagnetic, paramagnetic, and even nonmagnetic materials - a phenomenon reminiscent of the Barnett effect. These advancements showcase phonon chirality and angular momentum as powerful emerging tools for generating and controlling magnetism. This focus session aims to highlight the latest breakthroughs in chiral-phonon magnetism and foster connections between the rapidly evolving field of chiral phononics and the broader magnetism research community.

Coordinators: Dominik M.Juraschek, Eindhoven University of Technology, d.m.juraschek@tue.nl; Martina Basini, ETH Zürich, m.basini@ethz.ch

Time: Tuesday 9:30–12:45 Location: H16

MA 10.1 Tue 9:30 H16

Continuous-wave terahertz spectroscopy on chiral phonons — •Ji Eun Lee, Luca Eisele, Artem Pronin, and Martin Dressel — 1. Physikalisches Institut, Universität Stuttgart, Germany

We apply continuous-wave frequency-domain terahertz spectroscopy to study chiral phonons at low frequencies. As samples, we use thin films of materials with soft phonon modes, such as SrTiO3 and (doped) PbTe. Our experimental method utilizes both, measurements of transmission with circular-polarized light and Faraday-rotation experiments. In the talk, our approach to the measurements and preliminary results will be summarized.

MA 10.2 Tue 9:45 H16

Spin-lattice coupling in multiscale modeling: from angular momentum transfer to chiral phonons — •Markus Weissenhofer[1,2], Philipp Rieger[1], Sergiy Mankovsky[3], Akashdeep Kamra[5], MS Mrudul[1], Hubert Ebert[3], Ulrich Nowak[4], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Freie Universität Berlin, Berlin, Germany — [3]Ludwig Maximilian Universität, München, Germany — [4]Universität Konstanz, Konstanz, Germany — [5]Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany

Transfer and manipulation of angular momentum is a key aspect in spintronics. Recently, it has been shown that angular momentum transfer between spins and lattice is possible on ultrashort timescales [1]. To contribute to the understanding of this transfer, we have developed a theoretical multiscale framework for spin-lattice coupling, which is linked to ab-initio calculations on the one hand and magnetoelastic continuum theory on the other [2], allowing for the study of a wide range of magnetomechanical phenomena. Here I will discuss how this framework can be used to calculate magnon-phonon coupling parameters, emphasizing the importance of a Dzyaloshinskii-Moriya type interaction for angular momentum transfer [2] and revealing the existence of chiral phonons in iron arising from a chirality-selective coupling [3]. [1] Tauchert al., Nature 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). [3] Weißenhofer et al., arXiv:2411.03879.

MA 10.3 Tue 10:00 H16

Chiral phonon-induced magnetization reversal in 2D ferromagnets — •Daniel Bustamante Lopez[1] and Dominik Juraschek[2] — [1]Department of Physics, Boston University, Boston, Massachusetts 02215, USA — [2]Department of Applied Physics and Science Education, Eindhoven University of Technology, Eindhoven, Netherlands

In our previous work, we explored magnonic rectification, where a coherently excited chiral phonon generates an effective magnetic field capable of inducing quasistatic magnetization in antiferromagnetic materials. In this study, we extend this concept to ferromagnetic materials, demonstrating that phononic magnetic fields can achieve permanent magnetization reversal. We focus on two-dimensional chromium-based ferromagnetic crystals, including CrI3, CrGeTe3, and CrCl3, and investigate reversal mechanisms such as damping switching and precessional switching. Our findings reveal that phononic magnetic fields enable robust and permanent magnetization reversal within nanoseconds, highlighting their potential for ultrafast magnetic control.

MA 10.4 Tue 10:15 H16

Chiral phonons in coupled magnon-phonon band structure — •Yelyzaveta Borysenko, Daniel Schick, and Ulrich Nowak — University of Konstanz, Konstanz, Germany

Coupling of spin and lattice degrees of freedom in magnetic materials is a key aspect for angular momentum based information processing. During ultrafast demagnetization, spin angular momentum can be transferred into the lattice creating chiral phonons even in simple centrosymmetric materials [1]. Spin-lattice coupling mechanisms involved in such processes can be approached using first principles calculations, which allow to determine leading energy terms for angular momentum exchange for different materials [2, 3]. Coupled spin-lattice dynamics is then described constructing angular momentum-conserving Hamiltonian linked to ab initio calculated model parameters [4].

Here, we linearize the equations of motion and calculate coupled magnon-phonon dispersions. We discuss how different coupling terms, e.g., of anisotropy or Dzyaloshiskii-Moriya type, can modify magnon and phonon dispersions, open up energy gaps, lift the degeneracy of modes, and lead to avoided crossings in the band structure.

[1] S. R. Tauchert et al., Nature 602, 73 (2022); [2] S. Mankovsky et. al., Phys. Rev. Lett. 129, 067202 (2022); [3] J. Hellsvik et al., Phys. Rev. B 99, 104302 (2019); [4] M. Weißenhofer et al., Phys. Rev. B 108, L060404 (2023)

MA 10.5 Tue 10:30 H16

Phonon Inverse Faraday effect from electron-phonon coupling — •Natalia Shabala and Matthias Geilhufe — Department of Physics, Chalmers University of Technology, 412 96 Gothenburg, Sweden

The phonon inverse Faraday effect describes the emergence of a DC magnetization due to circularly polarized phonons. From time-dependent second order perturbation theory and electron-phonon coupling we develop a microscopic formalism for phonon inverse Faraday effect. We arrive at a general and material-independent equation [1]. Using this equation for ferroelectric soft mode in $SrTiO_3$ gives an estimate of effective magnetic field which is consistent with recent experiments [2]. Hence, our approach is promising for shedding light into the microscopic mechanism of angular momentum transfer between ionic and electronic angular momentum, which is expected to play a central role in the phononic manipulation of magnetism.

[1] N. Shabala and R. M. Geilhufe, Accepted to PRL, arXiv:2405.09538, 2024

[2] M. Basini et al., Nature 628, 534 (2024)

MA 10.6 Tue 10:45 H16

Temperature dependent magnon-phonon coupling in YIG/GGG heterostructures — •J. Weber[1,2], M. Cherkasskii[3], F. Engelhardt[3,4,5], S.T.B. Goennenwein[6], S.Viola Kusminskiy[3,5], 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, Munich, Germany — [3]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [4]Department of Physics, University Erlangen-Nuremberg, Erlangen, Germany — [5]Max Planck Institute for the Science of Light, Erlangen, Germany — [6]Department of Physics, University of Konstanz, Konstanz, Germany — [7]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Magnon-phonon coupling in heterostructures has recently gained interest in the context of angular momentum conversion and angular momentum transport via phonons. A typical experimental setting is a bilayer system, where the magnetization dynamics of a magnetic thin film interacts with the elastic standing wave excitations of a nonmagnetic bulk crystal. So far, bulk acoustic wave resonators consisting of a ferrimagnetic yttrium iron garnet (YIG) film deposited on a crystalline gadolinium gallium garnet (GGG) substrate have been studied at room temperature due to the favorable magnetic damping properties of YIG [1]. We present a temperature dependent analysis of the magnon-phonon coupling of a YIG/GGG bulk acoustic wave resonator.

[1] K. An et al., Phys. Rev. B **101**, 060407, (2020).

15 min. break

MA 10.7 Tue 11:15 H16

Modeling of the preparation and conservation of coherent phonon (pseudo) angular momentum — •Olga Minakova[1], Maximilian Frenzel[1], Carolina Paiva[2], Joanna M. Urban[1], Michael S. Spencer[1], Martin Wolf[1], Dominik M. Juraschek[2,3], and Sebastian F. Maehrlein[1,4,5] — [1]FHI Berlin — [2]Tel Aviv University — [3]Eindhoven University of Technology — [4]HZDR — [5]TU Dresden

The angular momentum of lattice vibrations - phonon angular momentum - is an underexplored degree of freedom in solid-state systems. Recent experiments have shown that circularly-polarized THz pulses can coherently excite degenerate phonon modes, enabling the preparation of phonon angular momentum states. THz-Kerr effect spectroscopy provides a means to monitor these states by directly measuring vectorial phonon trajectories. To interpret such experiments, it is essential to understand the symmetry properties of the phonon modes that influence the driving and probing processes, as well as the conservation of angular momentum in the crystal lattice. Here, we model the generation and detection of coherent phonon angular momentum, revealing how crystal symmetry dictates the selection rules in the lattice. We show that the form of the Raman tensors associated with the phonon explains the phonon helicity observed in experiments, linking the discrete rotational symmetry of the material to the conservation of pseudo angular momentum in lattice vibrations.

MA 10.8 Tue 11:30 H16

Spin-spin interaction via chiral phonons — •Daniel Schick[1], Markus Weissenhofer[2,3], Akashdeep Kamra[4], and Ulrich Nowak[1] — [1]University of Konstanz, Konstanz, Germany — [2]Uppsala University, Uppsala, Sweden — [3]Free University of Berlin, Berlin, Germany — [4]University of Kaiserslautern-Landau, Kaiserslautern, Germany

Coupling between the magnetic degrees of freedom and phonons has emerged as a topic of great importance for explaining various magnetic phenomena, like ultrafast demagnetization processes [1], and the possibility to affect magnetization dynamics via phonon pumping [2]. We develop a tool to study spin-lattice coupling in atomistic simulations, which conserves total angular momentum. This allows us to precisely retrace the transfer of angular momentum between the spin and lattice systems. We demonstrate the emergence of an effective spin-spin interaction mediated by chiral phonons. This effect can arise from thermal phonons as follows. A spin may precess after coupling to a phonon, with this precession producing chiral phonons, which in turn, affect other spins. A similar effect can be achieved by driving a spin to induce chiral phonons. We discuss the dependence of this interaction on the temperature and strength of the spin-lattice interaction and discuss our findings within the context of phonon-enhanced magnon transport phenomena.

[1] S. R. Tauchert, et. al., Nature **602**, 73 (2022)
[2] R.Schlitz et. al. Phys. Rev. B **106**, 014407 (2022)

MA 10.9 Tue 11:45 H16

Ultrafast generation of multicolor chiral phonons in magnetic and ferroelectric materials — •Omer Yaniv[1] and Dominik M. Juraschek[2] — [1]Tel Aviv University, Tel Aviv, Israel — [2]Eindhoven University of Technology, Eindhoven, Netherlands

Terahertz pulses are powerful tools capable of initiating coherent vibrational motions in solids. Circularly polarized pulses can further excite chiral phonons. Such phonons carry an angular momentum and are able to generate magnetic moments leading to a varying range of phenomena, including the phonon Hall, phonon Zeeman, and phonon inverse Faraday effects. Our study investigates the coherent driving of phonons using multicolor laser pulses, leading to Lissajous trajectories of the atoms. We demonstrate the generation of such multicolor chiral phonons in BaTiO3, a task that presents significant challenges due to the requirement of an exact 1:2 phonon frequency ratio. Achieving this precise ratio is crucial for the generation of closed atomic Lissajous loops. However, we overcome this challenge by creating phonon polaritons with shifted frequencies through the use of optical cavities. This approach allows us to surpass the limitations imposed by the strict phonon frequency ratio. By carefully tuning the cavity parameters, we demonstrate a new pathway for controlling lattice vibrations at ultrafast timescales. We also explore how multicolor phonons tune magnetic properties in monolayer CrI3, a 2D material with strong spin-orbit coupling and ferromagnetism. By manipulating phonon dynamics, we examine the interaction between lattice vibrations and magnetic order.

MA 10.10 Tue 12:00 H16

Chiral Phonons induced by Magnon-Phonon Coupling — •Hannah Bendin[1], Alexander Mook[2], Ingrid Mertig[1], and Robin R. Neumann[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle (Saale), Germany — [2]Johannes Gutenberg University, Mainz, Germany

Chiral phonons, the quasiparticles of circularly polarized lattice vibrations, have recently been investigated due to a range of emerging phenomena. Notably, chiral phonons carry nonzero angular momentum. However, the systems in which they occur still require extensive research. Chiral phonons may, for example, be found in lattices with broken inversion symmetry. Alternatively, they can be induced by the coupling to magnons, the quasiparticles of spin excitations, thereby lifting time-reversal symmetry.

Here, we analyze how magnetoelastic coupling gives rise to magnon-phonon hybridization, which, in turn, generates phonon angular momentum. Conversely, we show how the phonon angular momentum and the spin of the magnons affects their coupling strength. This interplay between magnons and chiral phonons allows for the tunability of the phonon angular momentum.

MA 10.11 Tue 12:15 H16

Ultrafast laser-induced carrier and magnetization dynamics in $SrTiO_3$ from real-time time-dependent DFT — •Andri Darmawan, Markus E. Gruner, and Rossitza Pentcheva — Department of Physics, University of Duisburg-Essen

Recent experimental studies indicate electric-field-driven ferroelectricity [1] and multiferroicity [2] in the paradigmatic nonmagnetic band insulator $SrTiO_3$ in the terahertz regime. Following a comprehensive study of the optical [3] and x-ray absorption [4] spectra including quasiparticle and excitonic effects, here we explore the response of $SrTiO_3$ to laser excitation. Using real-time time-dependent density functional theory (RT-TDDFT) as implemented in the Elk code, we investigate both linear and circular polarized laser pulses. A complex site- and orbital-dependent temporal dynamics is observed with opposite sign of fluctuations at O and Ti sites and charge transfer from O 2*p* to Ti 3*d* states for linearly polarized light, that breaks dynamically inversion symmetry. Notably, circularly polarized pulses induce a finite transient magnetic moment which is absent for linearly polarized pulses. Funding by DFG within CRC1242 (project C02) and computational time at magnitUDE, amplitUDE and the Leibniz Supercomputer Center (project pr87ro) are gratefully acknowledged.

[1] T.F. Nova et al., Science 364, 1075 (2019)
[2] M. Basini et al., Nature 628, 534 (2024)
[3] V. Begum, M.E. Gruner and R. Pentcheva, Phys. Rev. Mater. 3, 065004 (2019)
[4] V. Begum-Hudde et al., Phys. Rev. Res. 5, 013199 (2023)

MA 10.12 Tue 12:30 H16

Phonon pumping in ferromagnet/nonmagnetic insulator hybrid systems — •Richard Schlitz[1], Luise Holder[1], Johannes

Weber[2,3], Mikhail Cherkasskii[4], Fabian Engelhardt[4], Julie Střihavková[5], Matthias Althammer[2,3], Silvia V. Kusminskiy[4,6], Hans Huebl[2,3,7], and Sebastian T. B. Goennenwein[1] — [1]Department of Physics, University of Konstanz, Konstanz, Germany — [2]Walther-Meißner-Institut, BAdW, Garching, Germany — [3]School of Natural Sciences, TUM, Garching, Germany — [4]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [5]Faculty of Mathematics and Physics, Charles University, Prague — [6]Max Planck Institute for the Science of Light, Erlangen, Germany — [7]Munich Center for Quantum Science and Technology, München, Germany

In ferromagnetic thin films, magnetization dynamics, e.g., driven by ferromagnetic resonance, can coherently couple to phonons. If a ferromagnetic film is deposited on a crystalline substrate with polished parallel faces, the sample stack forms a bulk acoustic resonator, leading to characteristic modifications of the magnetic resonance signal.

In this work, we show that the magnetoelastic coupling can mediate the hybridization of the coherent magnetization dynamics with longitudinal and transverse phonons, with a particular dependence on the orientation of the magnetic field. We extract the magnetoelastic coupling parameters and compare them with theoretical expectations. Our results show that both longitudinal and transverse phonons can be efficiently excited, depending on the magnetic field orientation.

MA 11: Spin Transport and Orbitronics, Spin-Hall Effects I (joint session MA/TT)

Time: Tuesday 9:30–13:15 Location: H18

MA 11.1 Tue 9:30 H18

Topological orbital Hall effect caused by skyrmions and antiferromagnetic skyrmions — •Lennart Schimpf, Ingrid Mertig, and Börge Göbel — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

The topological Hall effect is a hallmark of topologically non-trivial magnetic textures such as magnetic skyrmions. It quantifies the transverse electric current once an electric field is applied and occurs as a consequence of the emergent magnetic field of the skyrmion. Likewise, an orbital magnetization is generated. Here we show that the charge currents are orbital polarized even though the conduction electrons couple to the skyrmion texture via their spin [1]. The topological Hall effect is accompanied by a topological orbital Hall effect even for *s* electrons without spin-orbit coupling. As we show, antiferromagnetic skyrmions and antiferromagnetic bimerons that have a compensated emergent field [2], exhibit a topological orbital Hall conductivity that is not accompanied by charge transport and can be orders of magnitude larger than the topological spin Hall conductivity.

[1] B. Göbel, L. Schimpf, I. Mertig, arXiv pre-print: 2410.00820
[2] B. Göbel, I. Mertig, O. Tretiakov, Physics Reports 895, 1 (2021)

MA 11.2 Tue 9:45 H18

Optimization of orbital torques in ferrimagnets and their relationship with Gilbert damping — •shilei ding, william legrand, hanchen wang, mingu kang, paul noel, and pietro gambardella — Department of Materials, ETH Zurich, 8093 Zurich, Switzerland

Application of an electric field can induce a non-equilibrium orbital angular momentum in conductive materials whose electronic bands have a k-dependent orbital character. This phenomenon can lead to the current-induced accumulation of orbital momenta in nonmagnetic layers, which can then diffuse into neighboring magnetic layers and interact with the local magnetization through spin-orbit coupling, giving rise to orbital torques. Conversely, the excitation of spin precession in a magnetic layer can give rise to an orbital current, resulting in orbital pumping and dissipation of angular momentum in the nonmagnetic layer. In the first part, I will present the efficacy of converting orbital to spin momenta in ferrimagnetic materials, specifically in the RE-TM ferrimagnet GdyCo100-y. This work underscores the mechanisms that facilitate orbital-to-spin conversion within a magnetic layer at the atomic level. In the second part, I will discuss how the Gilbert damping parameter correlates to spin and orbital torques in magnetic layers adjacent to Pt and CuOx layers, respectively. I will show that CoFe/CuOx bilayers exhibit a favorable combination of efficient orbital torque and minimal increase in Gilbert damping, which is promising for the implementation of orbital torque oscillators with reduced damping compared to spin torque oscillators.

MA 11.3 Tue 10:00 H18

Orbital magnetoresistance in insulating antiferromagnets — •Christin Schmitt[1], Sachin Krishnia[1], Edgar Galíndez Ruales[1], Takashi Kikkawa[2], Duc Tran[1], Timo Kuschel[1], Eiji Saitoh[2], Yuriy Mokrousov[1,3], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany — [2]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Insulating antiferromagnetic and ferrimagnetic materials are promising candidates for spintronic devices due to their intrinsic properties such as low damping [1]. Recently, orbital angular momentum (OAM) has emerged as a crucial concept in condensed-matter physics. Theoretical and experimental studies have highlighted that the orbital Hall effect (OHE) can enable orbital currents with efficiency orders of magnitude higher than that of spin Hall effects [2]. Here, we investigate magneto-resistance effects in magnetic systems [2,3]. We find that in TmIG the transverse magnetoresistance signal is increased significantly upon replacing Pt, a spin-current generator, by Cu*, a pure orbital-current generator. Further, we explore antiferromagnets with orbital magnetoresistance effects as pure orbital current is crucial for next generation pure orbitronics devices using abundant, cheap and environmentally friendly materials. [1] R. Lebrun, et al., Nature, 561, 222-225 (2018). [2] S. Ding, et al., Phys. Rev. Lett. 125, 177201 (2020). [3] S. Ding et al., Phys. Rev. Lett. 128, 067201 (2022).

MA 11.4 Tue 10:15 H18

Non-reciprocity in magnon mediated charge-spin-orbital current interconversion — •Sachin Krishnia[1], Omar Ledesma-Martin[1], Edgar Galindez-Ruales[1], Felix Fuhrmann[1], Duc Tran[1], Rahul Gupta[1], Marcel Gasser[1,2], Dongwook Go[1,2], Gerhard Jakob[1], Yuriy Mokrousov[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In magnetic systems, angular momentum is carried by the spin and orbital degrees of freedom. Non-local devices can be used to study angular momentum transport. They consist of parallel heavy-metal nanowires placed on top of magnetic insulators like yttrium iron garnet (YIG), facilitating the transmission of information by magnons, generated by the accumulation of spin at the interface, created via the spin Hall effect (SHE) and detected via the inverse SHE (iSHE). It has been demonstrated that these processes have comparable efficiencies when the role of the detector and injector is reversed, which points to reciprocity of the processes. However, we show that by adding Ru as a source of direct and inverse orbital Hall effect (OHE), the system no longer exhibits this reciprocity. Specifically, the generation of magnons via the combination of SHE and OHE and detection via the iSHE is found to be about 35% more efficient than the inverse process for our system [1]. [1] O. Ledesma et al., arXiv:2411.07044 (2024).

MA 11.5 Tue 10:30 H18

Detection of dynamic x-ray magnetic linear dichroism in NiO — •Timo Kuschel[1], Johannes Demir[1], Olga Kuschel[2], Joachim Wollschläger[2], and Christoph Klewe[3] — [1]Bielefeld University, Germany — [2]Osnabrück University, Germany — [3]Advanced Light Source (ALS), Berkeley, USA

Spin transport through thin antiferromagnetic layers such as NiO has been studied by ferromagnetic resonance (FMR) spin pumping [1], spin Seebeck effect [2], non-local magnon spin transport [3] and x-ray detected FMR (XFMR) [4]. In all these experiments, the spin current has been identified in an adjacent Pt layer [1-3] or FeCo film [4] via inverse spin Hall effect or dynamic x-ray magnetic *circular* dichroism, respectively, after having the NiO layer already passed.

In this contribution, we study Fe_3O_4/NiO/Pt [5] by XFMR and present the identification of dynamic x-ray magnetic *linear* dichroism (XMLD) [6] at the Ni L edges directly in the NiO layer for FMR spin pumping in the adjacent Fe_3O_4 layer. We will analyze the XFMR response depending on the NiO thickness. Further, we will discuss coupling phenomena at the NiO-Fe_3O_4 interface vs. spin transport through the NiO layer as the origin of the dynamic XMLD response.

[1] H. L. Wang et al., Phys. Rev. Lett. 113, 097202 (2014)
[2] W. Lin et al., Phys. Rev. Lett. 116, 186601 (2016)
[3] G. R. Hoogeboom et al., Phys. Rev. B 103, 144406 (2021)
[4] M. Dabrowski et al., Phys. Rev. Lett. 124, 217201 (2020)
[5] L. Baldrati et al., Phys. Rev. B 98, 014409 (2018)
[6] C. Klewe et al., New J. Phys. 24, 013030 (2022)

MA 11.6 Tue 10:45 H18

Manipulating the sign of the interlayer exchange coupling — •Nathan Walker — The Open University, Milton Keynes, UK

We demonstrate, using computer simulations and a non-equilibrium Greens function approach, that the sign of the out-of-equilibrium interlayer exchange coupling (ooeIEC) changes in the presence of an external bias. The system consists of a double barrier connected to an exchange coupled ferromagnetic tri-layer. We find a strongly non-linear dependence of the spin current on voltage which results in the exchange coupled tri-layer switching between parallel and antiparallel configurations. Our results are in excellent agreement with earlier theoretical calculations, which predict an approximately 2π topological phase change of the (equilibrium) IEC. We believe that this could act as an energy efficient mechanism for magnetic switching which does not rely on spin-transfer torque (STT). There are potential applications to magnetoresistive random-access memory (MRAM), one of the principal contenders for a universal memory.

MA 11.7 Tue 11:00 H18

Harnessing Orbital Hall Effect in Spin-Orbit Torque MRAM — •J. Omar Ledesma Martin[1,2], Rahul Gupta[1], Chloé Bouard[2], Fabian Kammerbauer[1], Iryna Kononenko[1], Sylvain Martin[2], Gerhard Jakob[1,3], Marc Drouard[2], and Mathias Kläui[1,3] — [1]1 Institute of Physics, Johannes Gutenberg University Mainz, 55099, Mainz, Germany — [2]Staudingerweg 7 — [3]Department of Physics, Center for Quantum Spintronics, Norwegian University of Science and Technology, 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 the spin Hall conductivity of Pt. [1] 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]x3/Co/MgO/CoFeB/Ta/Ru, where the OHE materials are Ru, Nb, and Cr. Additionally, a sample with Pt instead of OHE serves as a reference. The results demonstrate an improvement for the Ru samples, exhibiting higher damping-like torque and significantly 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.

[1] R. Gupta et al., arXiv:2404.02821 (2024). Nature Comm. In press (2024)

15 min. break

MA 11.8 Tue 11:30 H18

Spin and orbital Hall effect in metal systems: extrinsic vs. intrinsic contributions — •Sergiy Mankovsky and Hubert Ebert — LMU of Munich, 81377 Munich, Germany

Kubo's linear response formalism has been used to study the orbital Hall effect (OHE) for non-magnetic undoped and doped metallic systems, focusing on the impact of different types of disorder. Corresponding first-principles calculations of the orbital Hall conductivity (OHC) were performed making use of the KKR Green function method that allows in particular to monitor the impact of the vertex corrections on the OHC. The doping- and temperature-dependence of the OHC have been investigated and compared with corresponding results for the spin Hall conductivity (SHC). The temperature dependent properties of the OHC and SHC determined by thermally induced lattice vibrations (in non-magnetic materials) and spin fluctuations (in magnetic systems) have been accounted for making use of the alloy analogy model. For elemental systems at finite temperature a dominating role of the intrinsic contribution to the temperature-dependent OH and SH conductivities is found. In contrast, the OH and SH conductivities of doped systems at low temperatures are dominated by the SOC-driven extrinsic contributions strongly decreasing at higher temperatures due to the increasing impact of the electron-phonon scattering.

MA 11.9 Tue 11:45 H18

Simulations of spin transport in YIG — •Ben Schwanewedel, Moumita Kundu, and Ulrich Konstanz — Fachbereich Physik, Universität Konstanz, Konstanz, Germany

Being synthesized first in 1957, YIG has the lowest Gilbert damping among all known materials. This makes it interesting for spintronic applications and long-range spin transport. In YIG's complex unit cell Fe atoms occupy 20 sublattices leading to 20 magnon bands between 0 and 25 THz. We develop an atomistic spin model for YIG based on exchange interactions from Ref. [1], which were determined through neutron scattering. Further parameters were adapted from Ref. [2]. We varify our study through investigation of the magnon dispersion and comparing it to the results of Ref. [1].

We use atomistic spin dynamics simulations for the model above based on the stochastic Landau-Lifshitz-Gilbert equation to unravel its spin dynamics and spin transport properties. The spin transport is triggered by thermal gradients and and local magnetic fields and it is analyzed using an observable which is proportional to the magnon population. Also, magnon dispersions far from equilibrium are evaluated and discussed.

[1] Princep, Andrew J., et al. "The full magnon spectrum of yttrium iron garnet." npj Quantum Materials 2.1 (2017): 63.
[2] Barker, Joseph, and Gerrit EW Bauer. "Thermal spin dynamics of yttrium iron garnet." Physical review letters 117.21 (2016): 217201.

MA 11.10 Tue 12:00 H18

Orbital Hall effect accompanying quantum Hall effect — •Börge Göbel and Ingrid Mertig — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

The quantum Hall effect emerges when two-dimensional samples are subjected to strong magnetic fields at low temperatures: Topologically protected edge states cause a quantized Hall conductivity in multiples of e^2/h. Here we show that the quantum Hall effect is accompanied by an orbital Hall effect [1]. Our quantum mechanical calculations fit well the semiclassical interpretation in terms of "skipping orbits". The chiral edge states of a quantum Hall system are orbital polarized akin to an orbital version of the quantum anomalous Hall effect in magnetic systems. The orbital Hall resistivity scales quadratically with the magnetic field making it the dominant effect at high fields.

The discussion can be generalized to systems with effective magnetic fields: The topological Hall effect caused by the emergent field of topological spin textures, such as magnetic skyrmions, is accompanied by an orbital Hall effect, as well [2].

[1] B. Göbel, I. Mertig, Phys. Rev. Lett. 133, 146301 (2024)
[2] B. Göbel, L. Schimpf, I. Mertig, arXiv pre-print: 2410.00820

MA 11.11 Tue 12:15 H18

Large Spin Hall Angle in Mn-based Antiferromagnetic Alloys — •Nabil Menai[1], Martin Gradhand[2], and Derek Stewart[3] — [1]H. H. Wills Physics Laboratory, University of Bristol, Tyndall Ave, BS8-1TL, UK — [2]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany — [3]Western Digital Research Center, San Jose, California 95119, USA

Antiferromagnets (AFMs) have emerged as crucial materials for spintronic technologies for their ability to host spin-dependent transport phenomena, despite their zero net magnetization. Their robustness against external magnetic fields and ultrafast spin dynamics make them ideal for efficient spin-charge interconversion. In this theoretical study, we use density functional theory and Greens function methods to investigate the transport properties of Mn-based binary alloyed AFMs. Our focus is on the total spin Hall conductivity (SHC), accounting for both the intrinsic contributions from Berry curvature and the extrinsic effects from skew scattering and side-jump mechanisms. The objective is to identify AFM materials that exhibits a high spin Hall angle (SHA); with an efficient charge-to-spin Hall current conversion ratio. Our results reveal that doping MnPt with Ir significantly enhances the SHA, achieving a value of 8% at room temperature. In contrast, doping with Pd offers temperature stability with lower SHA values. Additionally, we examine the effects of substituting Mn atoms with magnetic transition metals such as Fe and Ni. These findings underscore the potential of antiferromagnetic alloys for efficient spin current generation.

MA 11.12 Tue 12:30 H18

Competing ordinary and Hanle magnetoresistance in Pt and Ti thin films — •Sebastian Sailler[1], Giacomo Sala[2], Denise Reustlen[1], Richard Schlitz[1], Min-Gu Kang[2], Pietro Gambardella[2], Sebastian T.B. Goennenwein[1], and Michaela Lammel[1] — [1]Department of Physics, University of Konstanz — [2]Department of Materials, ETH Zurich

One of the key elements in spintronics research is the spin Hall effect, allowing to generate spin currents from charge currents. A large spin Hall effect is observed in materials with strong spin orbit coupling, e.g. Pt. Recent research suggests the existence of an orbital Hall effect, the orbital analogue to the spin Hall effect, which also arises in weakly spin orbit coupled materials like Ti, Mn or Cr. In any of these materials, a magnetic field perpendicular to the spin or orbital accumulation leads to additional Hanle dephasing and thereby the Hanle magnetoresistance. Here, we studied the magnetoresistance (MR) of Pt thin films over a wide range of thicknesses. Careful evaluation shows that the MR of our textured samples is dominated by the so-called ordinary MR, while the Hanle effect does not play a significant role. Analyzing the intrinsic properties of Pt films deposited by different groups, we find that next to the resistivity, also the structural properties of the film influence which MR dominates. We further show that this correlation can also be found in orbital Hall active materials like Ti. We conclude that in all materials exhibiting a spin or orbital Hall effect, the Hanle MR and the ordinary MR coexist, and that the sample's purity and crystallinity determines which MR dominates.

MA 11.13 Tue 12:45 H18

Orbital Hanle magnetoresistance in Mn thin films — •Min-Gu Kang, Federica Nasr, Giacomo Sala, and Pietro Gambardella — Department of Materials, ETH Zurich, 8093 Zurich, Switzerland

Momentum-space orbital texture, or orbital character of electrons, enables the orbital Hall effect (OHE), a current-induced flow of nonequilibrium orbital angular momentum in centrosymmetric systems with negligible spin-orbit coupling. This orbital current, which can be orders of magnitude larger than its spin counterpart, offers transformative potential for spin-orbitronics, yet the mechanisms of orbital relaxation remain unclear. In this work, we present temperature-dependent orbital Hanle magnetoresistance and associated orbital relaxation mechanisms in Mn thin films. The results clearly show that the orbital Hanle magnetoresistance depends on the structure of the Mn thin films and can be associated with competing Dyakonov-Perel and Elliott-Yafet orbital relaxation effects. Our study highlights the critical role of orbital relaxation in determining the magnitude of current-induced orbital effects in 3d transition metal films.

MA 11.14 Tue 13:00 H18

Tuning of spin transport properties in 2D ferromagnet VSe_2 by structural polytypes of TaS_2 electrodes — •Biplab Sanyal and Masoumeh Davoudiniya — Department of Physics & Astronomy, Ångströmlaboratoriet, Uppsala University, Box-516, 75120 Uppsala, Sweden

2D magnets and their heterostructures are promising materials for future spintronic applications. Here, we present a study of spin transport through a ferromagnetic monolayer of 1T-VSe_2 with two structural polytypes of TaS_2 electrodes stacked in van der Waals heterostructures. Using density functional theory coupled with the nonequilibrium Green function framework, we explore the impact of TaS_2 electrode polytypes on the device's quantum transport properties. We observe that devices with 1T-TaS_2 electrodes exhibit higher spin-dependent transmission compared to 2H-TaS_2 electrodes. Incorporating MoS_2 as a tunnel barrier, anisotropic tunnel magnetoresistance enhances significantly, reaching 168% for the 1T-device and 1419% for the 2H-device. Spin-transfer torque (STT) analysis shows that its magnitude is highest at 90° (-702 μeV/V for 1T and -1561 μeV/V for 2H devices) and decreases towards 180°. The 1T-device shows superior performance with lower Gilbert damping, reduced critical current density and voltage for magnetization switching, compared to the 2H-device, which requires significantly higher current and voltage. Our predictions reveal the potential of 1T-VSe_2-based heterostructures for advanced spintronic applications.

MA 12: Magnetization Dynamics and Damping

Time: Tuesday 9:30–11:30 Location: H19

MA 12.1 Tue 9:30 H19

Oscillatory dynamics of strongly coupled magnetic domain walls in three-dimensional chiral nanostructures — •Pamela Morales Fernández[1,2], I. Konstantinos Douveas[3], S. Ruiz Gómez[4], E. Zhakina[1], L. Turnbull[1], M. König[1], A. Hierro Rodríguez[5], N. Leo[6], S. Finizio[7], S. Wintz[8], C. Abert[3], D. Suess[3], A. Fernández Pacheco[2], and C. Donnelly[1,9] — [1]MPI CPFS, Germany — [2]TU Viena, Austria — [3]University of Vienna, Austria — [4]ALBA Synchrotron, Spain — [5]Universidad de Oviedo, Spain — [6]Loughborough University, UK — [7]PSI, Switzerland — [8]BESSY II, Germany — [9]Hiroshima University, Japan.

The expansion of nanomagnetism into three dimensions opens opportunities for new topological textures, curvilinear effects, and exotic magnetization dynamics. Here, we investigate the magnetization dynamics in 3D double-helix nanostructures, which host strongly coupled domain wall pairs formed through the interplay of shape anisotropy, chirality, and inter-helix magnetostatic interactions. Using direct 3D nanofabrication techniques, cobalt nano double helices are grown on top of microwave antennas and exposed to GHz magnetic fields. Time-resolved scanning transmission X-ray microscopy reveals enhanced dynamics in the area of the coupled domain walls within the helical conduits. Observed dynamics depend on the geometrical parameters of the system and excitation frequency, matching with micromagnetic simulations that reveal additional higher-frequency modes beyond the reach of the experimental technique. This work provides insights into the physics of 3D nanomagnetism, advancing control for future technologies.

MA 12.2 Tue 9:45 H19

Anisotropic energy dissipation in model Kagome systems — Rajgowrav Cheenikundil[1], Zhiwei Lu[2], Ivan Miranda[3], Manuel Pereiro[4], and •Danny Thonig[1,4] — [1]Örebro University, Sweden — [2]KTH Royal Institute of Technology, Sweden — [3]Linnaeus University, Sweden — [4]University Uppsala, Sweden

Recent efforts have been directed towards understanding spin-orbit mediated phenomena such as the spin Hall effect [1], and energy dissipation phenomena [2], which are enhanced by non-collinear magnetism. Notably, the latter results in anisotropies in energy dissipation that have not been methodically investigated.

We employ the Kubo-Bastin formalism [3] of linear perturbation theory to calculate the non-local Gilbert damping tensor in a model Kagome system with Rashba spin-orbit coupling. This approach is implemented in the Cahmd code [4]. We vary the magnetic state according to different chiralities and phase differences.

Remarkably, the Bastin formalism connects the occurrence of anisotropic damping to a Fermi-sea contribution and, consequently, to spin-spin Berry curvature. Our systematic study examines the dependency of isotropic and anisotropic effective damping, as well as the full non-local damping, on electron lifetimes, Rashba parameters, and other factors. The results of this study pave the way for controlled dissipation in innovative spintronics applications.

[1] Scientific Reports 6, 28076 (2016); [2] Phys. Rev. Lett. 113, 266603 (2014); [3] Phys. Rev. B 102, 085113 (2020); [4] available at https://cahmd.gitlab.io/cahmdweb/

MA 12.3 Tue 10:00 H19

propelling ferrimagnetic domain walls by dynamical frustration — •reza doostani — university of cologne, cologne, germany

In this work, we realize the concept of active matter in a solid state system. By sending a ferrimagnet out of equilibrium by an oscillating magnetic field, we activate rotational goldstone mode where spins start to rotate clockwise or anti-clockwise depending on the ferromagnetic component. We see that in this setup, a domain wall moves actively to the left or right due to dynamical frustration. We further discuss the dynamics of these domain walls and the relation between domain wall motion and the external field amplitude, as well as their interaction and consequence of these on the whole system. Furthermore, we continue to study the effect of defects on the movement of domain walls.

MA 12.4 Tue 10:15 H19

Tunable magnetic easy axis orientation with ion irradiation — •Gabriel Gray[1], Kilian Lenz[1], Alexandra Lindner[1], Jürgen Lindner[1], Jürgen Fassbender[1], Fabian Ganss[1], Rodolfo Gallardo[2], and Pedro Landeros[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Material Research, Dresden, Germany — [2]Universidad Técnica Federico Santa María, Department of Physics, Valparaíso, Chile

Our research focuses on the ion-irradiation-induced changes in magneto-crystalline anisotropy and exchange coupling in epitaxially grown Fe thin films in the (110) orientation under ultra-high vacuum conditions on GaAs (110) single crystals. A Cr capping layer was deposited to prevent oxidation. The samples were irradiated with Cr ions at varying kinetic energies and fluences. Subsequent magnetic characterizations were performed using Ferromagnetic Resonance and Vibrating Sample Magnetometry techniques, while structural characterizations where perform using X-ray Diffractometry and Transmission Electron Microscopy.

Our results reveal a clear correlation between ion fluence and modifications in uniaxial magneto-crystalline anisotropy, while cubic anisotropy and the effective magnetization remain largely unaffected. Notably, the observed changes are sufficient to induce a reorientation of the easy axis of magnetization in the system.

MA 12.5 Tue 10:30 H19

Evidence of relativistic field-derivative torque in nonlinear THz response of magnetization dynamics — •Arpita Dutta[1], Christian Tzschaschel[2,3], Debankit Priyadarshi[3], Kouki Mikuni[4], Takuya Satoh[4,5], Ritwik Mondal[6], and Shovon Pal[1] — [1]NISER Bhubaneswar, HBNI, Jatni, India — [2]Max-Born Institute, Berlin, Germany — [3]ETH Zurich, Switzerland — [4]Institute of Science Tokyo, Japan — [5]Quantum Research Center for Chirality, Okazaki, Japan — [6]IIT (ISM) Dhanbad, India

The selective addressing of spins by terahertz (THz) electromagnetic fields via Zeeman torque is, by far, one of the most successful means of controlling magnetic excitations. Here, we show that the conventional Zeeman torque on the spin is not sufficient, rather an additional relativistic field derivative torque (FDT) is essential to realize the observed magnetization dynamics. We accomplish this by exploring the ultrafast nonlinear magnetization dynamics of a ferrimagnetic garnet when excited by two co-propagating THz pulses. Having identified the Kaplan-Kittel mode at 0.48 THz, resulting from the exchange interaction between the rare-earth and transition metal sublattices, we drive this mode to a nonlinear regime. We find that the observed nonlinear trace of the magnetic response cannot be mapped to the magnetization precession induced by the Zeeman torque, while the Zeeman torque supplemented by an additional FDT follows the experimental evidences.

[1] A. Dutta, *et al.*, Phys. Rev. Materials **8**, 114404 (2024).
[2] A. Dutta, *et al.*, arXiv:2408.05510 (2024).

MA 12.6 Tue 10:45 H19

Ferromagnetic resonance linewidth as a probe for investigating magnon-phonon interaction — •Gauravkumar Patel[1], Rodolfo Gallardo[2], Ruslan Salikhov[1], Sven Stienen[1], Kilian Lenz[1], Olav Hellwig[1,3], and Jürgen Lindner[1] — [1]Helmholtz-Zentrum Dresden–Rossendorf, Dresden, Germany — [2]Universidad Técnica Federico Santa María, Valpariso, Chille — [3]Chemnitz University of Technology, 09107 Chemnitz

The Ferromagnetic resonance (FMR) linewidth measurements provide information about dynamic energy losses present in magnetic materials. For materials with high magnetoelastic coupling strength, like Co, the uniform precession can excite the elastic vibrations in the underlying lattice. Using the FMR linewidth as a probe, we investigate this magnon-phonon interaction in Co thin films on Pt seed layers. This interaction results in a non-monotonic behavior of the linewidth as a function of frequency, showing multiple peaks at specific frequencies, in contrast to the typical Gilbert-like linear dependence. The magnon-phonon coupling is more pronounced in Co thin films with higher perpendicular anisotropy. Variation of the Co or Pt layer thickness shifts the linewidth peak position, indicating control over the frequency of the generated phonon.

MA 12.7 Tue 11:00 H19

Landau-Lifshitz damping from Lindbladian dissipation in quantum magnets — •Götz Uhrig — TU Dortmund University

As of now, the phenomenological classical Landau-Lifshitz (LL) damping of magnetic order is not linked to the established quantum theory of dissipation based on the Lindbladian master equation. This is an unsatisfactory conceptual caveat for the booming research on magnetic dynamics. Here, it is shown that LL dynamics can be systematically derived from Lindbladian dynamics using a local mean-field theory. Thereby, the successful LL approach is set on a firm quantum basis in the regime where the Lindblad approach is applicable. Furthermore, we extend the LL dynamics in a systematically controlled way to include not only changes of the orientation of the magnetization $\vec{m}$, but also of its length $|\vec{m}|$. The key aspect is that the Lindbladian relaxation must be adapted to the Hamiltonian $H(t)$ at each instant of time in time-dependent non-equilibrium systems. It is conjectured that this idea holds true well beyond the damping of magnetic dynamics given the appropriate hierarchy of time scales.

MA 12.8 Tue 11:15 H19

Dynamics of electronic phase separation at the laser-induced insulator/metal transition in LPCMO — •Maximilian Staabs, Tim Titze, Karen Stroh, Stefan Mathias, Vasily Moshnyaga, and Daniel Steil — I. Physikalisches Institut, Universität Göttingen, Göttingen, Deutschland

The closely related colossal magnetoresistive manganites LCMO and LPCMO exhibit surprising differences in their transient reflectivity dynamics after nanosecond pulsed laser excitation close to their metal-to-insulator transition (MIT). Transient resistance measurements reveal that both systems show transient metallization effects upon laser excitation in the vicinity of the static MIT. These are, however, weak and on the timescale of the laser pulse for LCMO, but much stronger and long-lived for LPCMO. We attribute the differences between these compounds to the presence of mesoscopic electronic phase separation in LPCMO in the MIT region, stabilized by Jahn-Teller polarons [1]. Laser excitation leads to the annihilation of Jahn-Teller distortions [2,3], thus enabling charge transfer between the formerly separated electronic phases. This process is observed as a collapse of the global electrical resistivity on the nanosecond timescale, whereas the recovery of the insulating phase separated state takes nearly 20 nanoseconds [4].

[1] V. Moshnyaga *et al.*, Phys. Rev. B **89**, 024420 (2014)
[2] M. Fiebig *et al.*, Appl. Phys. B **71**, 211 (2000)
[3] H. Matsuzaki *et al.*, Phys. Rev. B **79**, 235131 (2009)
[4] T. Titze *et al.*, Phys. Rev. Research **6**, 043168 (2024)

MA 13: Altermagnets II

Time: Tuesday 9:30–13:00 Location: H20

MA 13.1 Tue 9:30 H20

Dynamics of the altermagnetic candidate compound UCr_2Si_2C — Nikolaos Biniskos[1], •Manuel dos Santos Dias[2], Karin Schmalzl[3], Andrea Piovano[4], Ursula Bengaard Hansen[4], Michal Vališka[1], and Petr Čermák[1] — [1]Department of Condensed Matter Physics, Charles University, Praha, Czech Republic — [2]Scientific Computing Department, STFC Daresbury Laboratory, United Kingdom — [3]Jülich Centre for Neutron Science at ILL, Forschungszentrum Jülich, Grenoble, France — [4]Institut Laue-Langevin, Grenoble, France

Altermagnets are collinear antiferromagnets where spin degeneracy of the electronic bands or degeneracy of the magnon bands is not enforced by symmetry, potentially enabling diverse physical phenomena. However, it remains challenging to find materials that experimentally exhibit the hallmarks of altermagnetism. UCr_2Si_2C has been recently reported as a high-temperature antiferromagnet with a rare crystal structure that is compatible with altermagnetism [1]. This talk will report on our combined experimental and theoretical investigation of this compound. A large single crystal was successfully grown and experimentally investigated with bulk specific heat and magnetic susceptibility measurements, and through unpolarized and polarized inelastic neutron scattering. These experimental results have been interpreted with density functional theory calculations, providing a unified picture of UCr_2Si_2C and of its prospects as an altermagnet.

[1] Lemoine et al., Inorg. Chem. **57**, 2546-2557 (2018)

MA 13.2 Tue 9:45 H20

Theory of circular dichroism in resonant photoelectron diffraction of altermagnets — •Peter Krüger — Materials Science Dpt, Chiba University, Chiba 263-8522 Japan

Recently we have developed a computational method for resonant photoelectron diffraction (RPED) and its circular dichroism (CD) of magnetic surfaces, by combining ligand field multiplet and multiple scattering theory. The method was successfully tested for ferromagnetic Ni(111) [Phys. Rev. B 107, 075407 (2023)]. Here I apply the new method to the altermagnet MnTe. For a photon energy at the Mn L3-edge resonance and light incidence parallel to the magnetization axis, I show that there is a large, purely magnetic CD signal at the forward focusing peaks of the RPED pattern. This CD signal provides a direct probe of the staggered magnetization in altermagnets, which is closely related to the X-ray magnetic circular dichroism observed in ferromagnets.

MA 13.3 Tue 10:00 H20

New altermagnetic material candidates showing $4f$-magnetism — •Franziska Walther[1], Johannes Fey[1], Michelle Ocker[1], Libor Šmejkal[2,3], Cornelius Krellner[1], and Kristin Kliemt[1] — [1]Physikalisches Institut, Goethe-Universität 60438 Frankfurt/Main — [2]Max Planck Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — [3]Institut für Physik, Johannes Gutenberg Universität Mainz, 55099 Mainz

Altermagnets are a novel class of collinear magnetic materials, which are characterised by a vanishing net magnetization while breaking the time-reversal symmetry in the electronic band structure with a unique alternating spin-momentum locking [1]. So far, altermagnetism has been proven for magnetic $3d$-systems such as CrSb [2], MnTe [3] and Mn_5Si_3 [4] by the time-reversal breaking signature in the band structure or the observation of the anomalous Hall effect. In order to study the altermagnetism arising from local $4f$ moments, we have grown single crystals of lanthanoid-based intermetallic compounds and characterised their physical and chemical properties. We report on the crystal growth and measurements of magnetism, heat capacity and resistivity of the altermagnetic candidates.

[1] L. Šmejkal et al., Phys. Rev. X 12, 031042 (2022)
[2] S. Reimers et al., Nat. Commun. 15, 2116 (2024)
[3] J. Krempaský et al., Nature 626, 517 (2024)
[4] H. Reichlova et al., Nat. Commun. 15, 4961 (2024)

MA 13.4 Tue 10:15 H20

Altermagnetic properties of hematite. — •Edgar Galindez-Ruales[1], Rafael Gonzales-Hernandez[1,2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany. — [2]Grupo de Investigacíon en Física Aplicada, Departamento de Física,Universidad del Norte, Barranquilla, Colombia.

Hematite, a prototypical antiferromagnet, has emerged as a promising altermagnet due to its unique magnetic and electronic properties[1]. Unlike conventional antiferromagnets, altermagnets exhibit a nonzero anomalous Hall effect (AHE) due to symmetry-breaking electronic structures despite having no net magnetization. In hematite, we observe anisotropic magnetotransport with a strong crystal orientation dependence, including a striking sign inversion in the Hall effect[2]. Using advanced XMCD and XMLD imaging, we directly visualize and distinguish 180° domains, confirming the interplay between collinear antiferromagnetism and non-centrosymmetric atomic arrangements that drive the altermagnetic behavior. These findings provide robust experimental evidence of hematite*s altermagnetic nature, offering new mechanisms for identifying altermagnetic candidates and establishing hematite as a model system for exploring altermagnetic phenomena. This work paves the way for utilizing altermagnetic materials in spintronic applications, revolutionizing our understanding of magnetic material classification and transport phenomena. [1] L. Šmejkal et al., PRX 12, 040501 (2022). [2] E. Galindez-Ruales et al., ArXiv:2310.16907 (2023).

MA 13.5 Tue 10:30 H20

Ferro-spinetic altermagnetic insulators from electronic correlations — •Toshihiro Sato[1,2], Ion Cosma Fulga[1,2], Fakher F. Assaad[3,2], and Jeroen van den Brink[1,2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Germany — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany

While altermagnets are a class of fully compensated antiferromagnets lacking combined time-reversal and translational symmetry, their symmetry allows for unique polarization phenomena when inversion symmetry is broken. In this talk, we introduce an interacting fermion model with emergent ferro-spinetic polarizations in altermagnetic insulators - a spin analog to ferroelectricity. This model is grounded in a two-dimensional Hubbard framework incorporating inversion symmetry-breaking elements. Quantum Monte Carlo simulations demonstrate an altermagnetically ordered state with broken inversion symmetry driven by electron correlations, where spin-up and spin-down polarizations accumulate on opposite edges, with their directions reversibly controlled by the inversion symmetry-breaking factor. While the system retains electron-hole symmetry, resulting in zero ferroelectric charge polarization, breaking this symmetry induces the charge polarization orthogonal to the spin polarization.

MA 13.6 Tue 10:45 H20

Interplay of composition and magnetic properties in VxNbS2: An Altermagnetic candidate — •Sunil Wilfred Dsouza and Jan Minár — New Technologies Research Centre, University of West Bohemia, Univerzitní 8, CZ-306 14 Pilsen, Czech Republic

We investigate the interplay of chemical composition and electronic structure with respect to V atoms in an altermagnetic candidate VxNbS2 in the magnetically ordered state. The results from the first-principles calculations employing coherent potential approximation demonstrate that the electronic band structure exhibits valley-spin splitting induced by bulk magnetic order, which is only slightly affected by disorder and deficiency of V atoms, but an impact on the magnetic exchange coupling can be inferred. The results are interesting for the research on 3d-metal inserted transition-metal dichalcogenides and in a broader context for the understanding and design of Altermagnet-based spintronic materials.

MA 13.7 Tue 11:00 H20

Spin-transfer and topological Hall physics in d-wave altermagnets — •Ricardo Zarzuela — Johannes Gutenberg Universität Mainz, Mainz, Germany

Altermagnets, a novel magnetic phase of matter exhibiting zero net magnetization, anisotropic spin-split isoenergy surfaces and time reversal-symmetry-broken momentum-dependent spin splittings in the electronic band structure, have gained enormous momentum in the recent years due to their potential usage as active elements in Terahertz spintronic-based technologies [1]. In this talk, I will introduce an effective long-wavelength theory for charge carriers flowing within a d-wave altermagnet, from which the spin-splitter effect can be inferred as well as an unconventional spin-transfer response of the electron fluid. Reciprocally, the presence of altermagnetic textures induces the deflection of the electron trajectories. In this regard, I will also discuss how the d-wave nature of the altermagnet yields unconventional features to the topological Hall conductivity, which can be observed experimentally.

[1] L. Šmejkal, J. Sinova and T. Jungwirth, Phys. Rev. X 12, 031042 (2022); ibid. 040501 (2022).

15 min. break

MA 13.8 Tue 11:30 H20

Crystal structure and absence of magnetic order in single crystalline RuO_2 — •Lara Kiefer[1], Felix Wirth[1], Alexandre Bertin[1], Petra Becker[2], Ladislav Bohatý[2], Karin Schmalzl[3], Anne Stunault[4], José Alberto Rodríguez-Velemazan[4], Oscar Fabelo[4], and Markus Braden[1] — [1]II. Physic. Inst., Univ. Cologne, Germany — [2]Inst. Geology a. Mineralogie, Univ. Cologne, Germany — [3]Fz Jülich, Grenoble, France — [4]ILL, Grenoble, France

The recent report of antiferromagnetic order above room temperature in RuO_2 and its identification as an altermagnetic state boosted research on the material [1,2]. However, muon and neutron experiments, along with DFT calculations, recently questioned the existence of magnetic order in RuO_2 and suggested that it only occurs in the presence of vacancies [3-4]. We conducted polarized and unpolarized neutron diffraction experiments on RuO_2 crystals, which were characterized by magnetization, EDX, electrical conductance, and XRD measurements [5]. We did not confirm the proposed structural distortion in our crystals down to 2K. Ruthenium vacancies were below a few percent in our crystals. Polarized neutron experiments did not show magnetic Bragg reflections for the proposed $\vec{k}$=(0,0,0) [2]. Even a smaller ordered moment would have yielded significant intensities. Thus, this antiferromagnetic order is ruled out in our stoichiometric crystals [5]. [1] L. Ŝmejkal *et al.*, 2022, Phys. Rev. X **12(3)**, 031042.[2] T. Berjilin *et al.*, 2017, Phys. Rev. Lett. **118**, 077201.[3] A. Smolyanyuk *et al.*, 2024, Phys. Rev. B. **109**, 134424. [4] P. Keßler *et al.*, 2024, npj Spintronics **2**, 50. [5] L. Kiefer *et al.*, 2024, arXiv, 2410.05850.

MA 13.9 Tue 11:45 H20

Ferroelectric Switchable Altermagnetism — Mingqiang Gu[1], Yuntian Liu[1], Haiyuan Zhu[1], Kunihiro Yananose[2], Xiaobing Chen[1], Yongkang Hu[1], •Alessandro Stroppa[3], and Qihang Liu[1] — [1]Department of Physics and Guangdong Basic Research Center of Excellence for Quantum Science, Southern University of Science and Technology, Shenzhen 518055, China — [2]Korea Institute for Advanced Study, Seoul 02455, Republic of Korea — [3]CNR-SPIN - Via Vetoio - 67100 - Coppito (AQ), Italy.

We propose a novel ferroelectric switchable altermagnetism effect, by synergistically correlating the switching of ferroelectric polarization and the altermagnetic spin splitting. We demonstrate the design principles for the ferroelectric altermagnets and the further symmetry constraints for switching the altermagnetic spin splitting through flipping the electric polarization based on the state-of-the-art spin-group symmetry techniques. 22 ferroelectric altermagnets are found by screening through the 2001 experimental reported magnetic structures in the MAGNDATA database and 2 of them are identified as ferroelectric switchable altermagnets. Using the hybrid improper ferroelectric material [C(NH2)3]Cr(HCOO)3 as an example, we show how the altermagnetic spin splitting is tightly coupled to the ferroelectric polarization, providing an ideal platform for designing electric-field-controllable multiferroic devices. Finally, we find that such manipulation of altermagnetism can be detected by monitoring the physical quantities that are related to the non-vanishing Berry curvature dipole, such as the linearly polarized photogalvanic spin current.

MA 13.10 Tue 12:00 H20

Growth and properties of sputter-deposited altermagnetic RuO_2 thin films — •Maik Gaerner, Martin Wortmann, Judith Bünte, Inga Ennen, Andreas Hütten, Jan Schmalhorst, Timo Kuschel, and Günter Reiss — Bielefeld University, Germany

Altermagnetic materials exhibit time-reversal symmetry breaking and non-relativistic, anisotropic spin splitting in their bandstructure. RuO_2 is widely regarded as such an altermagnetic material, since e.g. spin-torque generation in RuO_2 has been observed [1]. However, muon spin rotation experiments [2] and density functional theory calculations [3] hint at the fragility of the magnetic order in RuO_2.

Here, we report on the growth and characterisation of RuO_2 thin films, deposited on MgF_2-, TiO_2- and MgO-substrates using reactive magnetron sputtering. In contrast to MgF_2-substrates, the lattice mismatch between the commonly used TiO_2-substrates and RuO_2 induces a significant strain on the RuO_2 which can enhance the density of states near the Fermi level [4]. We compare the crystallographic and electronic transport properties of the RuO_2 films, deposited at varying growth conditions and on the different substrates, with regard to the detection of the altermagnetic phase.

[1] Bose et al., Nat. Electron. 5, 267 (2022)
[2] Keßler et al., npj Spintronics 2, 50 (2024)
[3] Smolyanyuk et al., Phys. Rev. B 109, 134424 (2024)
[4] Ruf et al., Nat Commun 12, 59 (2021)

MA 13.11 Tue 12:15 H20

Thermo-electric magnetotransport studies on altermagnetic CrSb — •Sajal Naduvile Thadathil[1,2], T. Kotte[1], C. Müller[3], D. Kriegner[4], J. Pospíšil[4], R. Firouzmandi[5], M. Uhlarz[1], M. C. Rahn[2], T. Speliotis[6], V. Kocsis[5], J. Wosnitza[1,2], H. Reichlova[3], and T. Helm[1] — [1]High Magnetic Field Laboratory Dresden, (HLD-EMFL), HZDR, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Germany — [3]Institute of Physics, Academy of Science of the Czech Republic — [4]Charles University, Czech Republic — [5]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [6]Institute of Nanoscience and Nanotechnology, NCSR Demokritos

Recent observations of materials exhibiting properties of both ferromagnets and antiferromagnets, characterized by antiparallel magnetic ordering, have led to the classification of a third distinct magnetic phase known as "altermagnetism". In this study, we investigate the thermo-electric and magnetotransport properties of the altermagnetic candidate material CrSb, using bulk and micron-sized structures fabricated from single crystals. We performed measurements of thermal-transport, magnetoresistance (MR) and the Hall effect between 1.8 and 300 K under magnetic fields up to 14 T. Our results reveal a significant nonlinear field dependence of the Hall resistance, confirmed by similar nonlinear behavior in the thermal Hall effect, providing evidence for multiband physics in CrSb. Additionally, we observe a non-saturating MR up to 14 T. These findings provide new insights into the multiband electronic structure of CrSb.

MA 13.12 Tue 12:30 H20

SU(N) altermagnetism: Lattice models, magnon modes, and flavor-split bands — •Pedro Monteiro Cônsoli and Matthias Vojta — Institut für Theoretische Physik, TU Dresden

Altermagnets are magnetically ordered states which, much like antiferromagnets, have zero net magnetization, and yet resemble ferromagnets in that their band structure shows signs of broken time-reversal symmetry. They have stirred great interest lately not only due to their potential for spintronics applications, but also as gateways to unconventional phases of matter. In this talk, we will demonstrate that a generalized form of altermagnetism can occur in SU(N) magnets with $N > 2$. Guided by symmetry principles, we will present a recipe to construct simple Heisenberg models for such generalized altermagnets and apply it explicitly to two-dimensional examples with $N = 2$ and 3. We will then report a comparative analysis based on spin- and flavor-wave calculations which proves that both systems share the same characteristic behavior of insulating altermagnets, namely that their magnon bands are nondegenerate and carry different sets of magnetic quantum numbers. Finally, we will show that the analogy between the models persists when they are supplemented with charge carriers to become metallic.

MA 13.13 Tue 12:45 H20

Quasi-symmetry Constrained Spin Ferromagnetism in Altermagnets — Mercè Roig[1,2], Yue Yu[2], Rune C. Ekman[1], •Andreas Kreisel[1], Brian M. Andersen[1], and Daniel F. Agterberg[2] — [1]Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark — [2]Department of Physics, University of Wisconsin Milwaukee, Milwaukee, Wisconsin 53201, USA

Altermagnets break time-reversal symmetry and their spin-orbit coupling (SOC) allow for an anomalous Hall effect (AHE) that depends on the direction of the Néel ordering vector. AHE and ferromagnetic spin moment share the same symmetry and hence are usually proportional. However, density functional theory (DFT) calculations find that the AHE exists with negligible ferromagnetic spin moment for some compounds, whereas it reaches sizable values for other altermagnets. By examining realistic minimal models for altermagnetism in which the DFT phenomenology is captured, we uncover a general SOC-enabled quasi-symmetry that provides a natural explanation for the amplitude of the ferromagnetic spin moment across the vast range of different altermagnetic materials. Additionally, we derive analytic expressions for the magnetic anisotropy energy, providing a simple means to identify the preferred altermagnetic Néel vector orientation for altermagnets.

MA 14: Focus Session: Strongly Correlated Quantum States in Moire Heterostructures (joint session TT/HL/MA)

In recent years, significant progress has been made in realizing and exploring correlated quantum states in multilayer moiré heterostructures of graphene or transition metal dichalcogenides. These achievements have been made possible by the high level of control and tunability of these systems. Striking phenomena have been demonstrated experimentally, including unconventional superconductivity, fractional quantum anomalous Hall states, Mott-Wigner states and density waves, as well as kinetic ferromagnetism. Moreover, recently novel spectroscopic experimental techniques have been developed which allow for new ways to explore the dynamical response of these exotic states. This focus session will discuss recent experimental advancements as well as theoretical developments in the field of strongly correlated moiré heterostructures.

Organizers: Dmitri K. Efetov (LMU München), Michael Knap (TU München)

Time: Tuesday 9:30–13:15 Location: H36

Topical Talk MA 14.1 Tue 9:30 H36
The Thermoelectric Effect and Its Natural Heavy Fermion Explanation in Twisted Bilayer and Trilayer Graphene — Dumitru Calugaru[1], Haoyu Hu[2], Rafael Luque Merino[3], Nicolas Regnault[4], Frank Koppens[3], Dmitri K. Efetov[5], and •Bogdan Andrei Bernevig[1] — [1]Dept of Physics, Princeton University, Princeton, USA — [2]DIPC, San Sebastián, Spain — [3]ICFO, Barcelona, Spain — [4]Laboratoire de Physique de l'ENS, Paris, France — [5]LMU Munich, Munich, Germany

We study the interacting transport properties of twisted bilayer graphene (TBG) using the topological heavy-fermion (THF) model, where TBG comprises localized, correlated f-electrons and itinerant, dispersive c-electrons. The Seebeck coefficient of TBG exhibits unconventional traits: negative values with sawtooth oscillations at positive fillings, contrasting typical band-theory expectations. This behavior arises from the dichotomy between heavy (short-lived, correlated f-electrons) and light (long-lived, dispersive c-electrons), with transport dominated by c-electrons due to their stronger dispersion and longer lifetimes. At positive integer fillings, c- (f-)electron bands govern the electron (hole) doping side, resulting in an overall negative Seebeck coefficient. Sawtooth oscillations occur near each integer filling due to gap openings. Our results underscore the importance of electron correlations and lifetime asymmetry, naturally captured by the THF model, in understanding TBG transport properties. These findings align with experiments on twisted bilayer and trilayer graphene and highlight the interplay of heavy and light carriers.

Topical Talk MA 14.2 Tue 10:00 H36
Angle-Tuned Chiral Phase Transition in Twisted Bilayer Graphene — •Laura Classen[1,2], Nikolaos Parthenios[1,2], Cheng Huang[3], Xu Zhang[3], Maksim Ulybyshev[4], Fakher Assaad[3], and Zi Yang Meng[4] — [1]Max Planck Institute for Solid State Research — [2]Technical University of Munich — [3]University of Hong Kong — [4]University of Wuerzburg

The twist angle constitutes an important control knob in twisted bilayer graphene that has become accessible in-situ. It effectively tunes between weakly interacting, decoupled graphene layers and strongly correlated electrons at a magic angle of around 1.1 degree. We propose that this facilitates the realisation of a chiral phase transition of Dirac fermions at charge neutrality in twisted bilayer graphene. We argue that the transition can be described by the Gross-Neveu-Yukawa model that couples Dirac fermions and an XY order parameter field. The quantum critical behavior of this effective model is consistent with quantum Monte Carlo simulations of the continuum model for twisted bilayer graphene.

Topical Talk MA 14.3 Tue 10:30 H36
Quantum Optics of Semiconductor Moire Materials — •Atac Imamoglu — Institute of Quantum Electronics, ETH Zurich

Moire superlattices in two dimensional semiconductors have enabled the observation of a wealth of phenomena driven by strong electronic correlations, ranging from Mott-Wigner states to fractional quantum anomalous Hall effect. In this talk, I will present experiments exploring quantum optical control of strongly correlated electrons.

15 min. break

Topical Talk MA 14.4 Tue 11:15 H36
Probing the Band Structures of Multilayer Graphene Using the Quantum Twisting Microscope — •Martin Lee[1,2], Ipsita Das[1,2], János Papp[1,2], Marc Currle[1], Jiazhuo Li[1,2], Mudit Bhatt[1,2], Jonah Herzog-Arbeitman[3], Jiabin Yu[3], Zhiyuan Zhou[3], Markus Becherer[4], Philipp Altpeter[1], Christian Obermayer[1], Heribert Lorenz[1], Kenji Watanabe[5], Takashi Taniguchi[5], Bogdan Andrei Bernevig[3,6,7], and Dmitri Efetov[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Department of Physics, Princeton University, Princeton, New Jersey, USA — [4]School of Computation Information and Technology, Technical University of Munich, Germany — [5]National Institute of Material Sciences, Tsukuba, Japan — [6]Donostia International Physics Center, Donostia-San Sebastian, Spain — [7]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

Understanding the band-structure is foundational in describing the behavior of electrons in crystalline systems. While the tight-binding model effectively captures the non-interacting band-structures in materials like graphene, it relies on analytically or numerically derived hopping parameters. In this talk, we present the development of a quantum twisting microscope (QTM), which allows the k-resolved tunneling spectroscopy between the electronic states at the 2D tip and the 2D sample by twisting in-situ. Our QTM measurements allow us to extract the hopping parameters that agree with theoretical predictions.

Topical Talk MA 14.5 Tue 11:45 H36
Gate-Tunable Bose-Fermi Mixture in a Strongly Correlated Moiré Bilayer Electron System — •Nathan Wilson[1], Amine Ben Mhenni[1], Wilhelm Kadow[2], Mikołaj Metelski[1], Adrian Paulus[1], Alain Dijkstra[1], Jonathan Finley[1], and Michael Knap[2] — [1]Walter Schottky Institute, TU Munich, Garching, Germany — [2]School of Natural Sciences, TU Munich, Garching, Germany

Quantum gases consisting of species with distinct quantum statistics, such as Bose-Fermi mixtures, can behave in a fundamentally different way than their unmixed constituents. This makes them an essential platform for studying emergent quantum many-body phenomena such as mediated interactions and unconventional pairing. Here, we realize an equilibrium Bose-Fermi mixture in a bilayer electron system implemented in a WS_2/WSe_2 moiré heterobilayer with strong Coulomb coupling to a nearby moiré -free WSe2 monolayer. Absent the fermionic component, the underlying bosonic phase manifests as a dipolar excitonic insulator. By injecting excess charges, we show that the bosonic phase forms a stable mixture with added electrons but abruptly collapses upon hole doping. We develop a microscopic model to explain the unusual asymmetric stability with respect to electron/hole doping. By monitoring excitonic resonances from both layers, we demonstrate stability of the phase over a wide range in the boson/fermion density phase space, in agreement with theoretical calculations. Our results further the understanding of phases stabilized in moiré bilayer electron systems and demonstrate their potential for exploring the exotic properties of equilibrium Bose-Fermi mixtures.

MA 14.6 Tue 12:15 H36

Theory for Optical Control of Correlated States in Moiré Transition Metal Dichalcogenide Heterostructures — •Haoyang Tian and Urban Friedrich Peter Seifert — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77a, 50937 Köln, Germany

In recent years, moiré transition metal dichalcogenide (TMD) heterostructures have emerged as highly versatile platforms for investigating phases and phenomena of strongly correlated electrons on emergent lattice scales. However, experimental characterization of the precise nature of some interaction-driven long-range ordered states and their excitations has remained a challenge. Given strong light-matter couplings and valley selection rules in TMD materials, ultrafast optical methods may constitute a promising avenue for probing and controlling these states and their collective modes. In this work, we develop a theoretical framework to describe coherent light-matter interactions in moiré TMD heterostructures, and model the system's steady-state and non-equilibrium dynamics during and after photoexcitation with a laser pulse. Thus obtained characteristic signatures of the system's dynamics may allow for new experimental insights.

MA 14.7 Tue 12:30 H36

Single-Particle Spectral Function of Fractional Quantum Anomalous Hall States — •Fabian Pichler[1,2], Wilhelm Kadow[1,2], Clemens Kuhlenkamp[3,1,2], and Michael Knap[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts, USA

Fractional quantum Hall states are the most prominent example of states with topological order, hosting excitations with fractionalized charge. Recent experiments in twisted $MoTe_2$ and graphene-based heterostructures provide evidence of fractional quantum anomalous Hall (FQAH) states, which spontaneously break time-reversal symmetry and persist even without an external magnetic field. Understanding the unique properties of these states requires the characterization of their low-energy excitations. To that end, we construct a parton theory for the energy and momentum-resolved single-particle spectral function of FQAH states. We explicitly consider several experimentally observed filling fractions as well as a composite Fermi liquid in the half-filled Chern band. The parton description captures qualitatively our numerical exact diagonalization results. Additionally, we discuss how the finite bandwidth of the Chern band and the non-ideal quantum geometry affect the fractionalized excitations. Our work demonstrates that the energy and momentum-resolved electronic single-particle spectral function provides a valuable tool to characterize fractionalized excitations of FQAH states in moiré lattices.

MA 14.8 Tue 12:45 H36

Tuneability of Superconducting Properties in Transition Metal Dichalcogenide bilayers — •Michael Winter and Tim O. Wehling — I. Institut für Theoretische Physik, Universität Hamburg, Notkestraße 9-11, 22607 Hamburg

In recent years, rising interest sustained in van der Waals materials, particularly in transition metal dichalcogenides (TMDs or TMDCs). This work explores the potential for bilayer [hetero-]structuring in TMDs, which have garnered significant attention due to the discovery and prediction of exotic quantum phases, such as superconductivity and Mott insulating behaviour.

I present predictions derived from a minimal quantum lattice model, incorporating ab initio calculations based on plane-wave density functional theory (DFT), density functional perturbation theory (DFPT), and subsequent electron-phonon interaction calculations. The resulting model allows us to investigate the effects of different material combinations (e.g., MoS_2, $MoSe_2$, WS_2, WSe_2) and electron doping on superconductivity in such [hetero-]bilayer.

MA 14.9 Tue 13:00 H36

Proximity-Induced Spin-Triplet Superconducting Correlations in Transition Metal Dichalcogenides — •Florian Kayatz, Jorge Cayao, and Annica Black-Schaffer — Department of Physics and Astronomy, Uppsala University, Box 516, S-751 20 Uppsala, Sweden

The realization of spin-triplet Cooper pairs is a key ingredient for superconducting spintronics. One promising route to achieve this task is by exploiting the strong intrinsic spin-orbit coupling of transition metal dichalcogenides (TMDs). In this work, we consider a TMD layer coupled to a conventional spin-singlet s-wave superconductor and demonstrate the emergence of spin-triplet superconducting correlations. We find that these spin-triplet pair correlations form in the TMD as a proximity-induced effect but also appear in the superconductor as an inverse proximity effect and as a nonlocal phenomenon that exists between the TMD and superconductor. Furthermore, we relate these emergent superconducting correlations to experimentally observable features in the density of states and conductance.

MA 15: Poster I

Time: Tuesday 10:00–12:30 Location: P1

MA 15.1 Tue 10:00 P1

Truly Chiral Phonons Arising From Chirality-Selective Magnon-Phonon Coupling — •Philipp Rieger[1], Markus Weissenhofer[1,2], Luca Mikadze[1], M. S. Mrudul[1], Ulrich Nowak[3], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Freie Universität Berlin, Berlin, Germany — [3]Universität Konstanz, Konstanz, Germany

Growing attention has focused on the angular momentum of phonons, particularly in ultrafast magnetization dynamics. This arises from the circular or elliptical motion of atoms around equilibrium positions, forming collective modes known as chiral phonons.

Structural inversion symmetry (P) breaking is well known to give rise to chiral phonons. Here, we present an alternative mechanism for the generation of chiral phonons, stemming from magnon-phonon coupling in P-symmetric crystal lattices with time-reversal symmetry breaking.

We investigate magnon-phonon coupling in bcc Fe using a first-principles framework. Our calculations reveal the hybridization of magnon and phonon modes, giving rise to magnon-polarons and an avoided crossing (energy gap) in the dispersion relations. Along specific high-symmetry lines in reciprocal space, we observe that magnon coupling transforms degenerate transverse phonon modes into chiral phonons, characterized by an energy splitting between left- and right-handed modes. Our findings challenge conventional magneto-elastic interpretations and reveal zero-point phonon angular momentum and anomalous Hall effects linked to finite (spin) Berry curvatures.

MA 15.2 Tue 10:00 P1

Polymer-free stacking and μ-ARPES of multiferroic $CuCrP_2S_6$ — •Niklas Leuth[1], Tim Jacobs[1], Jeff Strasdas[1], Wendong Wang[2], Roman Gorbachev[2], Elena Voloshina[3], Yuriy Dedkov[3], Marcus Liebmann[1], Vitaly Feyer[4], and Markus Morgenstern[1] — [1]II. Institute of Physics B, RWTH-Aachen University, Germany — [2]National Graphene Institute, University of Manchester, UK — [3]Department of Physics, Shanghai University, China — [4]PGI 6, Forschungszentrum Jülich, Germany

Transition-metal (Tm) phosphorus trisulfides are antiferromagnetic van-der-Waals materials with various magnetic orders, providing a platform for detailed studying and tuning of 2D magnetism [1,2]. The binary Tm compound $CuCrP_2S_6$ exhibits additional ferro-/ antiferroelectricity and magnetoelectric coupling enabling gate induced magnetic orders [2]. We present results on stacking of this material by a fully inorganic transfer process in a glovebox developed by the University of Manchester, leading to polymer-free inter- and surfaces [3]. These stacks are analysed by atomic force microscopy and x-ray photoelectron spectroscopy. After transfer in ultra-high vacuum, they are suitable for surface-sensitive angular-resolved photoelectron spectroscopy (ARPES) with micrometre focus. We tracked the band structure from 300 K to 40 K covering several known phase transitions and discuss changes of the band structure in comparison with density functional theory calculations and analyse the relevant photoelectron matrix elements. [1] J. Mater. Chem. A, 2021, 9, 2560-2591. [2] Nat. Comm., 2024, 15, 3029. [3] Nat. Electron., 2023, 6, 981-990.

MA 15.3 Tue 10:00 P1

Towards time-resolved cubic Magneto-optic Kerr effect measurements — •Farell Keiser, Wentao Zhang, Yuhao Meng, Maik Gaerner, Nicolas Beermann, Hassan Hafez, Savio Fabretti, Timo Kuschel, and Dmitry Turchinovich — Bielefeld University, Germany

The magneto-optic Kerr effect (MOKE) represents an alteration in the polarization of light when it is reflected from a magnetized surface. MOKE-based techniques are widely employed to characterize the magnetic properties of thin films. While many experiments focus on first- or second-order MOKE [1,2], a systematic investigation of the third order "cubic MOKE" (CMOKE) was only reported recently [3]. In this study, we present time-resolved MOKE measurements in Ni(111) thin films to investigate the dynamics of CMOKE. Specifically, we measure MOKE-curves for different sample orientations under strong optical pumping to observe the influence of demagnetization on the CMOKE. Time-resolved MOKE measurements were performed for different sample orientations and pump fluences.

[1] R. Silber et al., Appl. Phys. Lett. 116, 262401 (2020)
[2] R. Silber et al., Phys. Rev. B 100, 064403 (2019)
[3] M. Gaerner et al., Phys. Rev. Applied 22, 024066 (2024)

MA 15.4 Tue 10:00 P1

Cubic magneto-optic Kerr effect in Ni(111) and Co(111) thin films depending on the angle of incidence — •Malte Schaeffer[1], Maik Gaerner[1], Robin Silber[2], Jaroslav Hamrle[3], Martin Wortmann[4], Andrea Ehrmann[4], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]VSB-Technical University of Ostrava, Czechia — [3]Charles University Prague, Czechia — [4]Bielefeld University of Applied Science and Arts, Germany

The magneto-optic Kerr effect (MOKE) describes the change in polarization of linear polarized light when reflected from a magnetized sample. It can be utilized to investigate magnetic properties of thin films and microstructures. In most cases, only the linear dependence on the magnetization M and sometimes the quadratic contribution depending on M^2 (QMOKE) are studied [1,2]. The third-order MOKE, so-called cubic MOKE (CMOKE), has only been studied recently [3,4]. In order to separate the individual MOKE contributions, the eight-directional method is used by applying an external magnetic field in eight different in-plane directions. In this contribution, we measured QMOKE and CMOKE in ferromagnetic Ni(111) and Co(111) thin films for different angles of incidence ranging from 45° to normal. We compared the findings with theoretical predictions based on Yeh's matrix formalism.

[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., Phys. Rev. Applied 22, 024066 (2024)
[4] See Focus Session 'Magneto-transport and magneto-optics of higher orders in magnetization' at DPG Meeting 2025 in Regensburg

MA 15.5 Tue 10:00 P1

Dynamical Mean Field Theory for Spin Systems at Finite Temperature — •Przemysław Bieniek, Timo Grässer, and Götz Uhrig — Technische Universität Dortmund, Fakultät Physik

In the recent years, a dynamical mean field theory approach for spin systems at infinite temperature (spinDMFT) was developed. It is an approximate technique in the limit of an infinite coordination number, reducing the full dynamics of a spin system to a problem of a single spin interacting with a dynamical environment field. This allows for very efficient computation of spin correlations, which shows good agreement with other computational techniques and excellently describes nuclear magnetic resonance (NMR) experiments.

However, the current version of spinDMFT applies only to systems at infinite temperature and two-site couplings. We aim at extending the technique. One goal is to address finite temperatures, but still above any ordering temperature. To this end, we modify the approach to dynamical Green's functions instead of spin correlations. The second goal is to deal with three-site couplings as they arise in experiments with magic angle spinning. We benchmark the developed techniques for various spin models by comparing the results with other numerical approaches and discuss possible applications.

MA 15.6 Tue 10:00 P1

Spin Textures and Surface State Sequences of a Prototypical Topological Insulator Revealed by Momentum Microscopy — •Wei-Sheng Chiu[1,2], Ina Marie Verzola[3], Ying-Jiun Chen[1,4], Rovi Angelo Beloya Villaos[3], Claus Michael Schneider[1,2], Feng-Chuan Chuang[3], and Christian Tusche[1,2] — [1]Forschungszentrum Jülich, Peter Grünberg Institut PGI-6, 52425 Jülich, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [3]National Sun Yat-sen University, Department of Physics, 80424 Kaohsiung, Taiwan — [4]Forschungszentrum Jülich,Ernst Ruska-Centre ER-C-1, 52425 Jülich, Germany

As a hallmark of the prototypical topological insulator of Bi_2Se_3, its intriguing topological surface state (TSS) has been extensively studied. By using spin-resolving momentum microscopy (SPEMM) with an Au passivated Ir(100) imaging spin filter, we directly recorded the spin-resolved momentum maps (k_x, k_y) over entire surface Brillouin zone (SBZ) of Bi_2Se_3. In addition to the well-known Dirac cone at the Fermi level, our measurements reveal a sequence of several Dirac-like spin textures and crossings. Our first-principles calculations indicate that those overlooked bands are attributed to Bi_2Se_3 surface states spanning a wide binding energy up to 4 eV below the Fermi level.

MA 15.7 Tue 10:00 P1

A single crystal study of the kagome magnets *R*Mn6Sn6 — •Ana Kurtanidze[1,2], Shingo Yamamoto[1], Klara Uhlirova[3], Yurii Skourski[1], Sergei Zherlitsyn[1], Jeremy Sourd[1], and Joachim Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden,Germany — [3]Materials Growth and Measurement Laboratory (MGML), Charles University, Prague, Czech Republic

The kagome magnets *R*Mn6Sn6 (*R* = Sc, Y, Gd-Lu) with hexagonal structure (P6/mmm) attract attention due to a possible correlation between the observed topological electronic properties and various magnetic phases. We synthesized high-quality single crystals of *R*Mn6Sn6 (*R* = Er and Tm) by a tin-flux method. We performed scanning electron microscopy, energy-dispersive x-ray spectroscopy, and wavelength dispersive x-ray fluorescence measurements to characterize the phase purity of the samples, which showed a composition close to the nominal stoichiometric ratio. We observed approximately 0.25 at.% aluminum impurity, which originated from the alumina crucibles used. In addition to the chemical characterization, we will discuss the magnetic properties from our preliminary magnetization results under magnetic fields applied along the principal crystallographic axes.

MA 15.8 Tue 10:00 P1

Static and dynamic magnetic properties in the Li-rich antiperovskite (Li_2Fe)ChO (Ch = S, Se) — •F.L. Carstens[1], F. Seewald[2], T. Schulze[2,3], N. Grässler[3], M.A.A. Mohamed[3], S. Hampel[3], L. Singer[1], H.-H. Klauss[2], H.-J. Grafe[3], and R. Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Institut für Festkörperphysik, TU Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research IFW Dresden, Germany

The recently discovered class of lithium-rich antiperovskites crystallize in cubic antiperovskite crystal structure such that Li^+ and transition metal ions TM^{2+} are randomly distributed at the same atomic position. They octahedrally coordinate central O^{2-} ions while the chalcogens (S^{2-}/Se^{2-}) are at corners of the cubic crystallographic cell. Despite their compelling properties as high-capacity cathode materials, very little is known about their electronic and magnetic properties. Here, we report static magnetisation, Mössbauer, and NMR studies on Li-rich antiperovskite (Li_2Fe)ChO (Ch = S, Se). Our data show a Pauli paramagnetic-like behaviour, a long-range antiferromagnetically ordered ground state and a regime of short-range magnetic order at least up to 100 K. Our results are consistent with predominantly random Li-Fe distribution on the shared lattice position. In addition, the effect of Li-hopping is observed and discussed. Overall, our data elucidate magnetism in a disordered presumably semimetallic system with thermally induced ionic dynamics.

MA 15.9 Tue 10:00 P1

Manipulation of Surface Domains in an Ultrasoft van-der-Waals Ferromagnet — •Stephan Schmutzler[1], Yichen Jin[1], Guangyao Miao[2,3], Florian Kronast[4], Sergio Valencia[4], Zefang Li[5], Martin Weinelt[1], and Cornelius Gahl[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Beijing National Laboratory for Condensed Matter Physics and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — [3]Department of Physics and CSMB, Humboldt-Universität zu Berlin, Berlin 12489, Germany — [4]Helmholtz-Zentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin, Germany — [5]School of Physics, Nankai University, Tianjin, China

The layered van-der-Waals material $Cr_2Ge_2Te_6$ (CGT) is a very soft ferromagnet at temperatures below 61 K. We show by X-ray magnetic circular dichroism in photoelectron emission microscopy (XMCD-PEEM) that the surface domain structure of a bulk CGT crystal can be reproducibly switched between topologically different phases by ultrashort laser pulse trains in combination with applying small magnetic fields. The effect is attributed to the transient temperature profile normal to the surface established by the interplay of absorption of light and the low interlayer heat conductivity of the material. The laser parameters accordingly allow for tayloring the sample depth of domain manipulation.

MA 15.10 Tue 10:00 P1

Sensing the Spin States of Individual Lanthanide Atoms on a surface — •Kyungju Noh[1,2,3], Gregory Czap[3], Jairo Velasco Jr.[3,4], Roger M. Macfarlane[3], Harald Brune[3,5], and Christopher P. Lutz[3] — [1]Center for Quantum 467 Nanoscience (QNS), Institute of Basic Science (IBS), Seoul 468 03760, Republic of Korea — [2]Department of Physics, Ewha 469 Womans University, Seoul 03760, Republic of Korea — [3]IBM Almaden Research Center, San Jose, 466 California 95120, United States — [4]Department of Physics, 472 University of California, Santa Cruz, California 95064, 473 United States — [5]Institute of Physics, Ecole 458 Polytechnique Fédérale de Lausanne (EPFL), Lausanne CH- 459 1015, Switzerland

Research on single atoms and molecules of lanthanide elements has become a focal point in materials science due to their exceptional magnetic and electronic properties arising from the 4f shell electrons.

Here, we introduce the magnetic property of individual Samarium (Sm) and Europium (Eu) atoms, which has nearly half-filled and half-filled 4f shell each, adsorbed on various binding sites of a MgO thin film. Using electron spin resonance scanning tunneling microscopy (ESR-STM), we analyze the spin structures of Sm and Eu on different binding sites. Titanium (Ti), a well-established atom, serves as a spin sensor to detect interactions with the lanthanide atoms. Our comparison across binding sites reveals distinct spin characteristics of the lanthanides on a surface, which further opens a way to implement lanthanide atoms to quantum devices.

MA 15.11 Tue 10:00 P1

Applications of 3D Nano-Lithography in Magnetism — •Jana Kredl[1], Christian Denker[1], Cornelius Fendler[2], Julia Bethune[1], Nina Meyer[1], Theresa Brinker[1], Finn-F. Stiewe[1], Hauke Heyen[1], Chris Badenhorst[1], Alena Rong[1], Jakob Walowski[1], Robin Silber[3], Mark Doerr[1], Raghvendra Palankar[1], Uwe T. Bornscheuer[1], Marcel Kohlmann[1], Toni Hache[6], Michaela Lammel[4], Alexander Paarmann[5], Andy Thomas[4], Robert Blick[2], Mihaela Delcea[1], and Markus Münzenberg[1] — [1]University of Greifswald, Germany — [2]University of Hamburg, Germany — [3]VSB-Technical University of Ostrava, Czech Republic — [4]IFW Dresden, Germany — [5]Fritz Haber Institute of Max Planck Society, Berlin, Germany — [6]Helmholtz-Zentrum Dresden-Rossendorf, Germany

3D 2-Photon-Lithography, originally developed for 3D photonic crystals, opens a wide range of new possible applications in many fields, e.g. life sciences, micro-optics and mechanics. We will present our recent applications of 3D 2-Photon-lithography and show 3D evaporation masks for in-situ device fabrication using different deposition angles, infra-red laser light focusing lenses directly fabricated on optical fibers, tunnel structures for guiding growth of neurons [1], pillars for investigation of cell mechanics and master-mold fabrication for Polydimethylsiloxane (PDMS) micro-fluidic channels. Based on our experience we will discuss possible applications in magnetism. [1] C. Fendler et al., Adv. Biosys. 5 (2019) doi: 10.1002/adbi.201970054

MA 15.12 Tue 10:00 P1

Straining three-dimensional magnetic nanostructures — •José Claudio Corsaletti Filho, Mohammad Sedghi, Elina Zhakina, Markus König, Elena Gati, and Claire Donnelly — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The study of nanoscale magnetic objects has led to fascinating discoveries over the past few decades. Three-dimensional magnetism offers new opportunities to develop compact energy storage devices and explore spin textures and novel domain walls, which could be crucial for energy-efficient computation. To improve our fundamental understanding and enable the development of new devices, it is important to be able to tune the magnetic properties of materials. One way to achieve the controlled manipulation of magnetic properties is through the application of strain. While the straining of materials is well established for both bulk, and thin film samples, applying strain to 3D magnetic nanostructures remains an open challenge. In this project we develop a protocol to strain three-dimensional cobalt nanostructures grown with focused electron beam induced deposition. By performing in-situ measurements as a function of applied strain, we explore first the mechanical properties of the 3D nanostructures under an electron microscope, and secondly, the evolution of the magnetic properties of the nanostructure with strain. The straining of magnetic nanostructures opens the door to control of magnetic textures in complex geometries, of key importance both to our fundamental understanding, and the development of new devices.

MA 15.13 Tue 10:00 P1

Micromagnetic Simulations of Domain Wall Dynamics in Chiral Nanostructures — •Iason-Konstantinos Douveas[1], Pamela Morales Fernandez[1,8], Sandra Ruiz- Gómez[3], Elina Zhakina[2], Sebastian Wintz[4], Markus König[2], Aurelio Hierro Rodríguez[5], Simone Finizio[6], Luke Turnbull[2], Naëmi Leo[7], Dieter Suess[1], Amalio Fernández-Pacheco[8], Claire Donnelly[2,9], and Claas Abert[1] — [1]Faculty of Physics, University of Vienna, Austria — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [3]ALBALBA Synchrotron Light Source, CELLS, Spain — [4]Helmholtz Zentrum Berlin BESSY II, Germany — [5]CINN CSIC, University of Oviedo, Spain — [6]Paul Scherrer Institut, Swiss Light Source, Switzerland — [7]Loughborough University, United Kingdom — [8]Institute of Applied Physics, University of Vienna, Austria — [9]International Institute for Sustainability with Knotted Matter, Japan

We investigate domain wall (DW) eigenmodes in three-dimensional chiral magnetic nanostructures through micromagnetic simulations using the finite-element method. Our study focuses on double helices under external magnetic fields, examining the relationship between DW behavior and structural parameters. We employ two computational approaches: a small-scale model for extensive parameter space exploration and a larger structure matching experimental specimens. By implementing X-ray magnetic circular dichroism simulations, we provide direct comparison with experimental data, offering insights into DW mechanics in curved geometries.

MA 15.14 Tue 10:00 P1

Developing a two sublattice model for spin inertia and nutation — •Tarek Moussa[1], Ritwik Mondal[2], and Akashdeep Kamra[1] — [1]Department of Physics, RPTU Kaiserlautern-Landau, Kaiserslautern, Germany — [2]Department of Physics, Indian Institute of Technology (ISM) Dhanbad, India

Recent theoretical and experimental works on ultrafast magnetization dynamics suggest the existence of a finite spin inertia resulting in a nutation mode. Using the Landau-Lifshitz-Gilbert equation, we develop a two sublattice model for the description of spin inertia on the basis of an effective spin-orbit-coupling description and results for two sublattice ferrimagnets. We examine the conditions under which the two-sublattice model leads us to the magnetization dynamics description including spin inertia.

MA 15.15 Tue 10:00 P1

Flip-flop transport of magnetic cuboidal particles in dynamic potential energy landscapes for Lab-on-Chip applications — •Jonas Bugase, Christian Janzen, Arne Vereijken, Yahya Shubbak, Nikolai Weidt, Rico Huhnstock, and Arno Ehresmann — Institute of Physics , University of Kassel, 34132 Kassel

The unique possibility to transport magnetic particles using controlled magnetic forces have resulted in their increased use in bio-applications. We, therefore, present the remotely controlled transport mechanism for cubiodal particles, fabricated using two-photon polymerization (2PP) lithography above a magnetically patterned flat substrate. By sputtering a magnetic exchange bias thin film system on the surface of the polymeric particles, we fix the magnetic moment of the particles along the elongated axis. We characterized the magnetic properties of the custom-made particles and studied their exotic transport within a periodic magnetic stray field landscape, artificially created by parallel stripe domains fabricated via ion bombardment induced magnetic patterning [1]. The shape anisotropy contributions and the rotation dynamics of the particles in a quiescent liquid environment leading to the lateral walking and flipping modes of the particle transport are characterized using optical microscopy. This transport mechanism is promising for the detection of biomolecules in Lab-on-Chip devices [2] and for probing the effective field direction of dynamically transformed magnetic stray field landscapes.

[1] Ehresmann *et al.* (2015), Sensors, (15): 28854.
[2] Lowensohn *et al.* (2020), Langmuir, (36): 7100.

MA 15.16 Tue 10:00 P1

Current status and outlooks in time-resolved scanning transmission X-ray microscopy imaging — Simone Finizio[1], Bart Olsthoorn[2], Joe Bailey[1], Claire Donnelly[3], Sina Mayr[1,4], Ales Hrabec[1,4], and •Jörg Raabe[1] — [1]Paul Scherrer Institut, Villigen PSI, Switzerland — [2]Nordita (KTH), Stockholm, Sweden — [3]MPI-CPFS, Dresden, Germany — [4]DMATL, ETH Zurich, Zurich, Switzerland

Time-resolved X-ray microscopy is a powerful imaging technique that has been extensively employed for the study of dynamical processes in condensed matter systems. In particular, time-resolved scanning transmission X-ray microscopy (TR-STXM) has been the workhorse in the experimental study of magneto-dynamical processes such as magnonics, switching, domain wall motion, and the dynamics of topological magnetic objects.

In this contribution, we will present the current status and outlooks of TR-STXM imaging at soft X-ray energies. The TR-STXM setup of the Swiss Light Source (SLS) will be presented, together with examples of 3D TR-STXM imaging, of periodogram-based imaging, and of how to overcome the limitations given by the X-ray pulse width.

In addition, we will present the planned future developments of the technique in view of the significant increase of coherent photon flux that will be offered by the upgrade of the SLS to a diffraction limited storage ring.

MA 15.17 Tue 10:00 P1

Micro-Hall magnetometry on magnetic grains and nanostructures — •Bereket Ghebretinsae and Jens Müller — Institute of Physics, Goethe University Frankfurt, 60438 Frankfurt (M), Germany

Micro-Hall magnetometry is a highly versatile and extremely sensitive magnetic measurement technique which allows for stray field measurements on micro- to nanosized samples with nanotesla sensitivity. The magnetometer is a Hall sensor based upon an AlGaAs/GaAs heterostructure which hosts a 2DEG whose unparalleled electron mobility in measurements directly translates into an ultrahigh stray-field resolution. Micro-Hall sensors have previously been used for diverse purposes such as resolving the discrete lattice potential inside a YIG thin film [1], pinpointing the onset of the formation of magnetic polarons inside ferromagnetic EuB_6 [2] as well as investigating the magnetostatics and the magnetization dynamics of two- and three-dimensional artificial spin ice systems [3]. Here we outline a (PhD) thesis project which intends to exploit the capabilities and the versatility of micro-Hall magnetometry to investigate a variety of magnetic systems of current scientific interest. We explain how micro-Hall measurements on specially prepared micron-sized YIG flakes, exchange-biased ferromagnetic bricks, and most of all, three-dimensional Co_3Fe nanotetrapod lattices serve to elucidate their characteristic properties and add upon our current understanding of the magnetism in these systems.

[1] K. Novoselov *et al.* Nature **426**, 812–816 (2003)
[2] M. Pohlit *et al.* Phys. Rev. Lett. **120**, 257201 (2018)
[3] L. Keller *et al.* Sci Rep. **8**, 6160 (2018)

MA 15.18 Tue 10:00 P1

Impact of sample dimensions on the anomalous Hall effect response — •Dominik Vogel, Denise Reustlen, Sebastian Sailler, Gregor Skobjin, Michaela Lammel, Richard Schlitz, and Sebastian T. B. Goennenwein — Fachbereich Physik, Universität Konstanz, Konstanz, Germany

The anomalous Hall effect (AHE) enables an electrical detection of the magnetization in ferromagnetic conductors. In typical AHE measurements, the voltage transverse to both the applied charge current and magnetic field is detected. Recording this voltage as a function of magnetic field strength and polarity allows one to infer the magnetic hysteresis loop of a given magnetic microstructure. However, the absolute magnitude of the AHE voltage characteristically scales with the sample dimensions. In particular, the smaller the width w of the respective studied Hall bar microstructure, the smaller the Hall voltage signal for constant current density. In order to establish the minimal sample dimensions required for a detectable AHE signal, we have systematically varied the dimensions of Hall bar microstructures patterned into thin Co/Pt multilayers with perpendicular magnetic anisotropy and measured their Hall response as a function of field magnitude and current density. We critically discuss the scaling of the Hall voltage with sample dimensions observed and its implications for Hall effect-based experiments in magnetic nanostructures.

MA 15.19 Tue 10:00 P1

Bright days ahead - Soft X-ray scanning microscopy at 4th generation lightsources — •Simone Finizio[1], Tim Butcher[1,2], Lars Heller[1], Benjamin Watts[1], Blagoj Sarafimov[1], Mirko Holler[1], and Jörg Raabe[1] — [1]Paul Scherrer Institut, Villigen PSI, Switzerland — [2]Max-Born-Institut, Berlin, Germany

Diffraction limited synchrotron (DLSR), or 4th generation, light sources are now delivering an increase in the coherent photon flux of several orders of magnitude compared to the current 3rd generation storage ring design, revolutionizing synchtrotron-based experiments.

For scanning transmission X-ray microscopy (STXM), the increase in coherent photon flux will allow us to routinely perform high-resolution imaging, as it will tackle all the issues occurring for high-resolution X-ray optics. In addition, the combined increase in coherent photon flux, in the available (GPU) computational power, and in the performances of 2D soft X-ray detectors will also enable for the routine performing of high-resolution soft X-ray ptychographic imaging.

In this presentation, we will show the current status of the commissioning of a new combined STXM and soft X-ray ptychography endstation at the SoftiMAX beamline of the MaxIV DLSR, and the first results in the ptychographic imaging of the magneto-electric coupling between ferroelectric domains and spin cycloid in freestanding BiFeO3 thin films, which fully exploit the sub-5nm spatial resolutions achievable with the technique.

MA 15.20 Tue 10:00 P1

Theory of Magnetization Dynamics Control by Phonons — •Meritxell Valls Boix and Alexander Mook — Johannes Gutenberg University, Mainz

Spin-lattice coupling plays a crucial role in facilitating angular momentum exchange between the lattice and magnetic subsystems. In this work, we explore how this coupling can be harnessed to enhance the lifetime of magnons in ferromagnetic materials. Specifically, we focus on the interaction between propagating surface acoustic waves and a proximate magnetic system, where these waves generate a torque on the spins. Using perturbation theory, we derive the effective field arising from magneto-rotational coupling and subsequently define the resulting torque. In particular, we investigate whether a damping-like component of the torque can emerge, which could act as an anti-damping mechanism to counteract the intrinsic magnon damping.

MA 15.21 Tue 10:00 P1

Prospects of spin dynamic mean-field theory for nuclear magnetic resonance — •Timo Gräßer and Götz S. Uhrig — Condensed Matter Physics, TU Dortmund University, Germany

The recently developed dynamic mean-field theory for spins at infinite temperature (spinDMFT) [1] is perfectly tailored to simulate NMR experiments. The underlying idea of spinDMFT is to couple a spin to a dynamic Gaussian mean-field with second moments that are self-consistently linked to the spin's autocorrelations. The approach can be straight-forwardly improved by considering clusters of spins quantum-mechanically in a mean-field background [2,3]. As such, the extension to a non-local spinDMFT (nl-spinDMFT) has been successfully benchmarked for calcium fluoride (CaF_2) and adamantane ($C_{10}H_{16}$) [3]. Due to the low computational requirements and the high flexibility of the method, it can be applied to various scenarios in NMR such as magic angle spinning (MAS) or spin diffusion.

[1] T. Gräßer et al., Phys. Rev. Research 3, 043168 (2021).
[2] T. Gräßer et al., Phys. Rev. Research 5, 043191 (2023).
[3] T. Gräßer et al., Solid State NMR 132, 101936 (2024).

MA 15.22 Tue 10:00 P1

Micromagnetic simulation of an X-shaped crossing controlled by the orientation of an external bias magnetic field — •Sven Niehues, Robert Schmidt, Jannis Bensmann, Steffen Michaelis de Vasconcellos, and Rudolf Bratschitsch — Institute of Physics, University of Münster, Germany

Magnonics is a well-known research field in solid-state physics, which studies magnetic phenomena and the propagation of spin waves and their respective quanta, called magnons. The possibility of steering the propagation direction of spin waves in magnetic insulators such as yttrium iron garnet (YIG) is of crucial importance for the realization of magnonic logic devices. By changing the orientation of the external bias magnetic field relative to the propagation direction, the propagation of spin waves can be manipulated. In this work, numeric simulations of an X-shaped YIG crossing are presented, which allows the steering of spin waves from one input arm into all three output arms at selected frequencies by rotation of the magnetic bias field.

MA 15.23 Tue 10:00 P1

Coupled dynamic modes of a skyrmion chain in a synthetic antiferromagnet (SAF) — •Kauser Zulfiqar[1,2,3], Samuel Holt[1,3], Martin Lang[1,3], Swapneel Amit Pathak[1,3], and Hans Fangohr[1,3,4] — [1]Max Planck Institute for the Structure and Dynamics of the Matter, Hamburg, Germany. — [2]University of Hamburg, Hamburg, Germany. — [3]Center for Free Electron Laser, Hamburg, Hamburg, Germany. — [4]University of Southampton, Southampton, United Kingdom.

Synthetic antiferromagnets (SAFs) are multilayer structures with ferromagnetic layers coupled via RKKY interaction [1]. Skyrmions in SAFs are smaller than in ferromagnetic systems, and studying their modes provides insights into their dynamics and stability, enhancing their potential for spintronic devices [2].

In this work, we expand on previous studies of skyrmion dynamics in circular geometries [3] by exploring a chain of Néel-type skyrmions in a rectangular strip using finite-difference micromagnetic simulations [4]. We use the ringdown method to excite the system with a sinc pulse. Through Fourier analysis, we identify individual modes and observe hybrid and coupled breathing modes among layers.

This work is funded by Marie Skłodowska-Curie (grant 101152613), MaMMoS (Horizon Europe, grant 101135546), and HEC-DAAD (ID 57630247).

[1]. Physical Review B 94, 064406 (2016) [2]. Applied Physics Letters 118, 082403 (2021) [3]. Physical Review B 102, 104403 (2020) [4]. IEEE Transactions on Magnetics 58, 1-5 (2022)

MA 15.24 Tue 10:00 P1

Spin dynamics in ferrimagnetic heterostructures — •Felix Fuhrmann[1], Akashdeep Akashdeep[1], Sven Becker[1], 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

Magnons emerge as promising information carriers for energy-efficient technology. To advance magnon-based devices, crucial materials requirements must be addressed. Yttrium Iron Garnet (YIG, $Y_3Fe_5O_{12}$) and related garnets, like Gadolinium Iron Garnet (GdIG, $Gd_3Fe_5O_{12}$), stand out due to low damping and large magnon propagation lengths. Using pulsed laser deposition, we fabricated YIG/GIG heterostructures and simulated their magnetic properties. Our findings reveal ferromagnetic coupling between Fe sublattices, leading to complex magnetic response and nontrivial temperature dependence [1]. Experiments on spin current generation via spin Seebeck effect and spin pumping at ferromagnetic resonance align with our micromagnetic simulations [2]. These results provide insights for magnon-based devices and highlight YIG/GIG heterostructures' potential in spintronics applications. [1] S. Becker et al., Phys. Rev. Appl., 16, 014047 (2021). [2] F. Fuhrmann et al., ArXiv:2303.15085 (2023).

MA 15.25 Tue 10:00 P1

Magnetization fluctuations probed via the anomalous Hall effect — •Nadine Nabben[1], Giacomo Sala[2], Ulrich Nowak[1], Matthias Krüger[3], and Sebastian T. B. Goennenwein[1] — [1]Universität Konstanz — [2]ETH Zürich — [3]Universität Göttingen

Fluctuation phenomena inherently limit the precision of physical measurements, making it essential to understand the underlying mechanisms for improving measurement accuracy. In particular, analyzing magnetic fluctuations provides valuable insights into magnetization behavior and domain wall dynamics. We employ the anomalous Hall effect to electrically investigate low-frequency magnetization fluctuations in thin ferromagnetic layer stacks with perpendicular magnetic anisotropy. By examining the anomalous Hall effect noise at different points in the hysteresis loop, we probe the distinct types of magnetic noise associated with different magnetization states. Our results show that Barkhausen noise, exhibiting a characteristic $1/f^2$ frequency dependence, dominates as long as magnetic relaxation processes occur. In contrast, quasi-stationary magnetization fluctuations generate noise that obeys a $1/f$ frequency dependence. We discuss how these findings offer new perspectives on magnetic fluctuation mechanisms and their implications for both fundamental understanding and technical applications.

MA 15.26 Tue 10:00 P1

Micromagnetic Mumax3 simulations of spin-waves under the influence of stray field landscapes — •Fabian Samad[1,2], Attila Kákay[2], and Olav Hellwig[1,2] — [1]University of Technology Chemnitz, Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

In most spin-wave application concepts the capability of manipulating and confining the spin-waves is pivotal. One promising way is the usage of hybrid systems [1,2], where the spin-wave transport layer is not directly manipulated, e.g. by patterning, but instead is influenced by a "programming" layer. In our study, we choose for the programming layer a synthetic antiferromagnet (SAF) with perpendicular magnetic anisotropy (PMA) [3], which acts on a spin-wave transport layer via its stray field. The SAF can exhibit a variety of magnetic states depending on the energy parameters and the applied magnetic field, making it – and thus the hybrid system – field-reconfigurable. By performing Mumax3 simulations, we investigate the influence of the stray field of various magnetic patterns in the SAF on the spin-wave dispersion in a layer with YIG-type properties. Particularly, we focus on regular and periodic magnetic domains in the SAF, which can be stabilised e.g. by means of focussed ion beam irradiation and manipulated with external magnetic fields [4].

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

MA 15.27 Tue 10:00 P1

Quantum spin liquid mimicry in correlated proton disorder double hydroxide perovskite $CuSn(OD)_6$ — •Anton Kulbakov[1], Ellen Haeussler[2], Aswathi Mannathanath Chakkingal[1], Nikolai Pavlovskii[1], Kaushick Parui[1], Sergey Granovsky[1], Sebastian Gass[3], Laura Teresa Corredor Bohorquez[3], Anja Wolter[3,4], Vladimir Pomjakushin[5], Darren Peets[1], Thomas Doert[2], and Dmytro Inosov[1,4] — [1]IFMP, TUD, Dresden, Germany — [2]Faekultaet fuer Chemie und Lebensmittelchemie, TUD, Dresden,Germany — [3]IFW, Dresden, Germany — [4]Wuerzburg-Dresden ct.qmat, TUD, Dresden, Germany — [5]PSI, Villigen, Switzerland

In a magnetic double perovskite hydroxide $CuSn(OD)_6$, the frustration of the proton network coexists with magnetic frustration on the distorted fcc sublattice. Structural distortions, which are most pronounced in the Cu^{2+} compounds due to the Jahn-Teller effect, partially alleviate both frustrations. On the other hand, the quantum spin $S = \frac{1}{2}$ promotes quantum fluctuations that lower the ordering temperature. Proton disorder is also expected to suppress long-range order tendencies from most general considerations, as it should lead to variations in the exchange constants, which can effectively be described as bond disorder in the spin model. In certain scenarios, these can destroy long-range order in favor of spin-liquid-mimicry.

MA 15.28 Tue 10:00 P1

Observation of the spiral spin liquid in a triangular-lattice material — •Nikita Andriushin[1], Stanislav Nikitin[2], Oystein Fjellvag[2,3], John White[2], Andrey Podlesnyak[4], Dmytro Inosov[1], Marein Rahn[6,1], Marcus Schmidt[5], Michael Baenitz[5], and Aleksandr Sukhanov[6,1] — [1]TU Dresden, Germany — [2]PSI, Switzerland — [3]IFE, Norway — [4]ORNL, USA — [5]MPI CPfS, Dresden, Germany — [6]Augsburg University, Germany

The spiral spin liquid (SSL) is a highly degenerate state characterized by a continuous contour or surface in reciprocal space spanned by a spiral propagation vector. Although the SSL state has been predicted in a number of various theoretical models, very few materials are so far experimentally identified to host such a state. Via combined single-crystal wide-angle and small-angle neutron scattering, we report observation of the SSL in the quasi-two-dimensional delafossite-like $AgCrSe_2$ [1]. We show that it is a very close realization of the ideal Heisenberg J_1–J_2–J_3 frustrated model on the triangular lattice. By supplementing our experimental results with microscopic spin-dynamics simulations, we demonstrate how such exotic magnetic states are driven by thermal fluctuations and exchange frustration.

[1] N. D. Andriushin, *et al.*, arXiv:2410.04954 (2024).

MA 15.29 Tue 10:00 P1

Magnetism in i-Tb-Cd quasicrystals — •Andreas Kreyssig — Institute for Experimental Physics 4, Ruhr-Universität Bochum, 44801 Bochum, Germany

i-Tb-Cd orders as icoshedral quasicrystal with the magnetic Tb3+ ions arranged in Tsai-type clusters. We studied the magnetic correlations and excitations by elastic and inelastic neutron scattering on single-grain isotopically enriched samples. The measurements of the crystalline electric field excitations demonstrated that the Tb3+ moments are directed along the local fivefold axes of the Tsai-type clusters. By using a simple Ising-type model for the moment configurations on a single Tb3+ icosahedron, we calculated the magnetic diffuse scattering for the low-energy configurations and identified the most likely moment configuration in a single cluster by comparison with our diffuse neutron scattering signals. We further studied the role of intercluster interactions for magnetic frustration and the magnetic scattering.

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MA 15.30 Tue 10:00 P1

Magnetism in i-Tb-Cd quasicrystals — •Andreas Kreyssig[1,2], P. Das[2], G. S. Tucker[2], A. Podlesnyak[3], Feng Ye[3], Masaaki Matsuda[3], T. Kong[2], S. L. Bud'ko[2], P. C. Canfield[2], R Flint[2], P. P. Orth[2,4], T. Yamada[5], and A. I. Goldman[2] — [1]Experimental Physics IV, Ruhr University Bochum, Bochum, Germany — [2]Ames Laboratory, U.S. DOE, and Department of Physics and Astronomy, Iowa State University, Ames, USA — [3]Neutron Scattering Division, Oak Ridge National Laboratory, USA — [4]Department of Physics, Harvard University, Cambridge, USA — [5]Department of Applied Physics, Tokyo University of Science, Tokyo, Japan

i-Tb-Cd orders as icoshedral quasicrystal with the magnetic Tb^{3+} ions arranged in Tsai-type clusters. We studied the magnetic correlations and excitations by elastic and inelastic neutron scattering on single-grain isotopically enriched samples. The measurements of the crystalline electric field excitations demonstrated that the Tb^{3+} moments are directed along the local fivefold axes of the Tsai-type clusters. We calculated the magnetic diffuse scattering for the low-energy configurations using an Ising-type model for the moment arrangements on a single Tb^{3+} icosahedron. By comparison with our diffuse neutron scattering signals, we identified the most likely moment configuration in a single cluster. We further studied the role of intercluster interactions for magnetic frustration and the magnetic scattering.

This work was supported by the U. S. DOE, BES, DMSE, Contract DE-AC02-07CH11358, and resources at HFIR and SNS, U. S. DOE.

P. Das, A. Kreyssig, et. al., Phys. Rev. **B** 108, 134421 (2023).

MA 15.31 Tue 10:00 P1

Frustrated magnetism in hydrogenated hexagonal Boron Nitride — •Maksim Ulybyshev, Manish Verma, and Giorgio Sangiovanni — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

We study monolayer hexagonal boron nitride (h-BN) with hydrogen adatoms arranged in a regular triangular lattice. Extensive density functional theory (DFT) calculations reveal a flat band formed by electronic states localized near the adatoms, situated within the band gap of h-BN. Based on these results, we construct a tight-binding model that captures the essential features of this band structure and derive an effective Hamiltonian for electrons in the flat band. This effective Hamiltonian incorporates the effects of long-range Coulomb interactions projected onto the flat band using a technique previously validated by Quantum Monte Carlo simulations of similar systems. We demonstrate that the lack of particle-hole symmetry in this system causes the projected long-range Coulomb interactions to induce frustrated spin couplings between electrons localized near neighboring adatoms. Depending on the spatial configuration of the adatoms, this frustration can give rise to various nontrivial magnetic states.

MA 15.32 Tue 10:00 P1

Geometrical frustration mediated unconventional magnetism in a Kondo lattice Ce3ZrBi5 — •Saswata Halder, Arumugam Thamizhavel, and Kalobaran Maiti — Tata Institute of Fundamental Physics, Mumbai, India

Kondo lattice materials with geometric frustration offer fertile ground for exploring exotic new physics with a field-induced fractional magnetization platform. In this work, we investigate hexagonal Ce3ZrBi5 with 1D Bi chains and a frustrated Ce-kagome network to understand its magnetic properties. Density functional theory (DFT) calculations reveal the presence of a non-trivial electronic structure, that changes significantly in the presence of SOC. The temperature dependent magnetization for Ce3ZrBi5 show the presence of two antiferromagnetic (AFM) transitions below TN = 4.9 K; highlighting a complex and highly anisotropic magnetic landscape. The magnetization shows a peculiar nature where the moments align along the CEF hard axis; contrary to conventional antiferromagnets. The unconventional magnetization can be attributed to multiple observables: geometric frustration, presence of competing Kondo and RKKY nergy scales and strong spin- orbit coupling (SOC). Field-induced metamagnetic transitions are observed in the isothermal magnetization data which follows the one-third magnetization rule observed in frustrated Kagome lattices. Specific heat and transport measurements highlight inherent Kondo-lattice characteristics in Ce3ZrBi5. Our work establishes Ce3ZrBi5 and related materials as a unique platform for exploring low-dimensional quantum fluctuations in frustrated antiferromagnets.

MA 15.33 Tue 10:00 P1

Flat bands and megnetoelectric effect in XX sawtooth chain with three-spin interactions — •Karen Baghdasaryan[1], Vadim Ohanyan[2,3], Ostap Baran[4], and Oleg Derzhko[4] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Yerevan State University, Yerevan, Armenia — [3]CANDLE Synchrotron Research Institute, Yerevan, Armenia — [4]Institute for Condensed Matter Physics, Lviv, Ukraine

We present an exact analysis of the XX sawtooth chain with three-spin interactions and the Katsura-Nagaosa-Balatsky (KNB) mechanism. Using Jordan-Wigner fermionization, we identify all zero-temperature phases of the model and observe the emergence of a flat band in the free-fermion spectrum. These flat bands result in jumps in observables such as magnetization and dielectric polarization as functions of both magnetic and electric fields.

MA 15.34 Tue 10:00 P1

Two-dimensional coherent spectroscopy as a probe for spin-1 single ion bound states — •Sagar Ramchandani[1], Yoshito Watanabe[1], Simon Trebst[1], and Ciarán Hickey[2,3] — [1]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — [2]School of Physics, University College Dublin, Belfield, Dublin 4, Ireland — [3]Centre for Quantum Engineering, Science, and Technology, University College Dublin, Dublin 4, Ireland

Nonlinear spectroscopy has emerged as a powerful prospect to probe quantum magnets by extracting information from higher-order responses. In this work, we report on the implementation of 2-dimensional coherent spectroscopy (2DCS) in the context of the Su(n)ny Julia package for modelling atomic-scale magnetism. We employ this code (and its semi-classical approach) to study the properties of spin-1 single ion bound states (SIBS), motivated in part by recent experiments on FeI_2.

MA 15.35 Tue 10:00 P1

Theoretical study on in-plane, out-of-plane, and transverse anisotropic magnetoresistance effects for ferromagnetic films — •Satoshi Kokado[1] and Masakiyo Tsunoda[2] — [1]Shizuoka University, Hamamatsu, Japan — [2]Tohoku University, Sendai, Japan

We theoretically study the in-plane [1], out-of-plane [2], and transverse anisotropic magnetoresistance (AMR) effects [3] for a strong ferromagnet, Fe_4N. We here use the electron scattering theory with an extrinsic mechanism, in which the conduction electron is scattered into the conduction state and the localized d states by impurities and so on [4]. The in-plane and out-of-plane AMR effects exhibit the negative AMR ratio with the twofold symmetry, while the transverse AMR effect shows the positive AMR ratio with the fourfold symmetry. The calculation results agree qualitatively well with the respective experimental results [1,2,3] for Fe_4N. In addition, the peak structures of the AMR ratios reflect the probability densities of the current direction of the single atomic d states.

[1] M. Tsunoda et al., APEX **3**, 113003 (2010).
[2] M. Tsunoda et al., unpublished.
[3] K. Kabara et al., AIP advances **6**, 055818 (2016).
[4] S. Kokado et al., J. Phys. Soc. Jpn. **91**, 044701 (2022), J. Phys. Soc. Jpn. **81**, 024705 (2012), Adv. Mater. Res. **750-752**, 978 (2013), Jpn. J. Appl. Phys. **55**, 108004 (2016), J. Phys. Soc. Jpn. **88**, 034706 (2019).

MA 15.36 Tue 10:00 P1

Preparation and characterization of $Co_{20}Fe_{80}Si_x$ thin films — •Florian Knossalla, Maik Gaerner, Luca Kempe, Karsten Rott, Jan Schmalhorst, and Günter Reiss — Bielefeld University, Germany

In spintronics, materials with favorable magnetic properties, such as large magnetic polarization and a high Curie temperature are essential. By means of machine learning, different Fe-Co-Si compounds were identified as promising [1]. This study focuses on the investigation of alloys with the composition $Co_{20}Fe_{80}Si_x$.
The samples were fabricated using DC and RF magnetron co-sputtering. Subsequently, temperature-dependent resistance measurements, investigations of the ordinary and the anomalous Hall effect were performed alongside with measurements of the anisotropic magneto-resistance.
The magnetic polarization decreased with increasing silicon content, from approximately 2 T for $Co_{20}Fe_{80}$ to about 0.5 T for $Co_{20}Fe_{80}Si_{100}$. In the latter, a phase transition at 60K was observed, which coincides with the appearance of a linear nonsaturating magnetoresistance. Interestingly, $Co_{20}Fe_{80}Si_{50}$ exhibited a higher magnetic polarization than $Co_{20}Fe_{80}Si_{25}$, as well as twice the charge carrier density compared to $Co_{20}Fe_{80}$.

[1]Timothy Liao u. a. Phys. Rev. Materials 7, 034410(2023)

MA 15.37 Tue 10:00 P1

Real-time in-situ giant magnetoresistance measurements in Co/Cu multilayers during sputter deposition — Michael Mattern, •Luca Kempe, Jan 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 is 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 15.38 Tue 10:00 P1

Quantitative study of the spin Hall magnetoresistance in a yttrium iron garnet/Pt heterostructure — •Denise Reustlen, Sebastian Sailler, Davina Schmidt, Richard Schlitz, Michaela Lammel, and Sebastian T. B. Goennenwein — Department of Physics, University of Konstanz, 78457 Konstanz

The spin Hall magnetoresistance (SMR) is a well-known and extensively studied phenomenon in the field of spintronics. The SMR is most commonly observed in heterostructures consisting of a ferromagnetic insulator and a normal metal with a large spin orbit interaction. In this study, we use yttrium iron garnet as the ferrimagnetic insulator and platinum as the normal metal due to its relatively large spin Hall angle. While the SMR is usually measured locally, on a single Hallbar structure, the data obtained often are used to gauge the magnetic quality of the underlying magnetic insulator or of the magnet/metal interface. Interestingly, however, up to now little is known about the SMR statistics in one Hallbar and the scatter of the SMR magnitude across several Hallbars on a single sample. Given that the SMR is a local effect, it is relevant to ascertain the significance of a single measurement as a representative measure for the entire sample. We thus have patterned more than 200 nominally identical SMR microstructures into a single YIG/Pt bilayer and studied the statistical distribution of the SMR as a function of position across the entire sample. Our results demonstrate that the SMR amplitude is robust and provide the basis for a consistent comparison of the SMR.

MA 15.39 Tue 10:00 P1

Spin Textures Stability in Exfoliated Fe3GaTe2 Two-Dimensional Magnets — •Kai Litzius[1], Yara Mahboub[2], Krishnanjana Puzhekadavil Joy[2], Steffen Wittrock[1], Lilian Prodan[1], István Kézsmárki[1], and Felix Büttner[1,2] — [1]University of Augsburg, Augsburg, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Two-dimensional (2D) van der Waals magnets have emerged as an exciting area of research, providing unique opportunities to study magnetism in reduced dimensions. Among these materials, Fe3GaTe2 is

particularly notable for its exceptionally high Curie temperature [1], which enables investigations and device applications at room temperature. Moreover, its structural and compositional similarity to Fe3GeTe2, one of the most extensively studied 2D magnets, suggests significant potential for tuning its magnetic properties [2,3], making it a promising candidate for both fundamental research and spintronic device applications. In this study, we explore the spin texture stability of Fe3GaTe2 thin flakes, prepared through mechanical exfoliation, using magnetic force microscopy (MFM). We also assess their resistance to oxidation [4] and degradation under ambient conditions, confirming their robust performance. These results highlight Fe3GaTe2 as a high-TC, stable 2D magnet, well-suited to advancing research in 2D magnetism and enabling next-generation spintronic technologies. References: [1] H. Shi et al., Nano Lett. 24, 11246 (2024). [2] Y. Wu et al. Nat. Commun. 11, 3860 (2020). [3] M. T. Birch et al. 2D Mater. 11, 025008 (2024). [4] D. S. Kim et al. Curr. Appl. Phys. 30, 40 (2021).

MA 15.40 Tue 10:00 P1

Electrical detection of spin currents in magnetic insulators — •Ankita Nayak[1], Matthias Kronseder[2], Nynke Vlietstra[3], Hans Huebl[3,4,5], Jeroen A. Heuver[6], Beatriz Noheda[6], Maxim Mostovoy[6], Christian Back[3,4], and Aisha Aqeel[1,3,4] — [1]University of Augsburg, 86135, Augsburg, Germany — [2]Department of Physics, Regensburg University, 93053, Regensburg, Germany — [3]Department of Physics, Technical University Munich, 85748 Garching b. München, Germany. — [4]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799, München, Germany. — [5]Walther -Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748, Garching, Germany, — [6]Zernika Institute for Advanced Materials, University of Groningen, Nijenborgh 4, 9747 AG, Groningen, The Netherlands.

We investigate the spin current-induced phenomena, such as spin Hall magnetoresistance and the spin Seebeck effect within Pt films deposited on a noncollinear magnet [1], CoCr2O4 (CCO). CCO is a spinel with a collinear ferrimagnetic state below Tc = 94 K and noncollinear magnetic phases at lower temperatures [2]. We investigated the SMR and the SSE at different temperatures (5K-300K) [2]. The temperature-dependent behavior of both SMR and SSE signals exhibits a noticeable variation correlated with different magnetic phases of CCO. This study offers insights into spin-current-driven phenomena, paving the way for potential spintronic applications. [1]. A. Aqeel, et al., Phys. Rev. B 103 (10), L100410 (2021). [2]. A. Aqeel, Phys. Rev. B 92 (22), 224410 (2015).

MA 15.41 Tue 10:00 P1

First principle study of Spin and charge transport properties in CrO2/CrI3/Td-WTe2/CrO2 based device heterostructures — •Nivedita Pandey and Oscar Granas — Department of Physics and Astronomy, Uppsala University, SE-751 20 Uppsala, Sweden

Van der Waals heterostructures are attractive for spintronic applications due to tunability of electronic, and magnetic properties. Herein, we show that precise control over spin injection and filtering can be achieved by interfacing magnetic and non-magnetic 2D layers, and these properties are robust to electrode attachment. We study a bilayer of CrI3/WTe2, using electrode CrO2 to design a promising spintronic device. We use density functional theory, capturing charge transport and thermal properties through the use of the non-equilibrium Green function. Integration of ferromagnetic CrI3 with either metallic or semiconducting phase of WTe2 results in substantially different properties of the interface. Further, the coupling between magnetism, and charge/spin transport has been studied in detail for both parallel magnetization and anti-parallel magnetization case. The spin polarized current with variation in the electrode temperature has been calculated for the designed CrO2/CrI3/WTe2/CrO2 device, further the spin filtration efficiency is extracted to understand the effect of temperature on spin filtration. The proposed device shows a spin filtration efficiency of around 100% at the studied temperatures. In addition, a high thermal magnetoresistance has been obtained for the designed device.

MA 15.42 Tue 10:00 P1

Workflow for Robust Code and Data Management exemplified for the numerical calculation of the Hopf index — •Jonas Nothhelfer, Ross Knapman, and Karin Everschor-Sitte — Universität Duisburg-Essen

Structured workflows for code and data management are essential in scientific projects to ensure reproducibility and quality. We will discuss these workflows from a system administrator's perspective, emphasizing the infrastructure and tools needed to support scientific computing. Using a recent scientific project as a case study, we present an example workflow that makes the projects numerical methods for calculating the three-dimensional topological Hopf index accessible [1]. Not only do we offer Python scripts, but we also develop extensions for the standard micromagnetic software tool, Mumax3 [2]. Code management is handled through GitLab, ensuring access to the most current versions of code [3], while Zenodo is used to provide persistent identifiers for released versions [4].

[1] R. Knapman, et al. arxiv:2410.22058 (2024).

[2] A. Vansteenkiste, et al. AIP Adv. 4, 107133 (2014).

[3] https://git.uni-due.de/twist-external/numericalhopfindexcalculation.

[4] https://zenodo.org/records/14007386, https://zenodo.org/records/14006

MA 15.43 Tue 10:00 P1

Angle-resolved calculation of magnetocrystalline anisotropy using symmetry-adapted Wannier functions — •Hiroto Saito and Takashi Koretsune — Tohoku University, Sendai, Japan

Magnetocrystalline anisotropy is one of the most fundamental physical quantities that determine the properties of magnetic materials. However, since its value is often very small, dense k-mesh is needed to accurately calculate it using first-principles calculations. We have previously developed a method to calculate magnetocrystalline anisotropy with high precision and low computational cost by constructing a Wannier tight-binding model that incorporates both crystal and spin symmetries, and by using the time-reversal-symmetry operation to separate the magnetization and spin-orbit interaction [1, 2].

Recently, a systematic approach for generating a complete set of symmetry-adapted multipole bases has been developed to describe the electronic degrees of freedom in crystals [3]. In this study, we apply this method to demonstrate that symmetry-adapted Wannier Hamiltonians for magnetic materials can be expanded using multipole bases. This finding highlights the feasibility of constructing symmetry-based effective models directly from first-principles calculations. As a practical application, we report the calculation results of the magnetic anisotropy of anomalous Hall conductivity.

[1] T. Koretsune, Comput. Phys. Commun. **285**, 108645 (2023).
[2] H. Saito *et al.*, Comput. Phys. Commun. **305**, 109325 (2024).
[3] H. Kusunose *et al.*, Phys. Rev. B **107**, 195118 (2023).

MA 15.44 Tue 10:00 P1

Discretization Anisotropy In Micromagnetics — Samuel Holt[1,2], •Andrea Petrocchi[1,2], Martin Lang[1,2], Swapneel Pathak[1,2], and Hans Fangohr[1,2,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Faculty of Engineering and Physical Sciences, University of Southampton, Southampton SO17 1BJ, United Kingdom

Micromagnetics models the physics of magnetic systems using partial differential equations to express quantities such as the magnetization, energy density, and effective field. The discretization of these equation onto a regular lattice produces anisotropy. Its impact is extensive and includes phenomena such as the energy-minimizing rotation of magnetic structures, preferred directions, and creating artificial magnetization structures.

Despite this, the consequences of discretization anisotropy and how to mitigate against it are rarely discussed in the context of micromagnetics. A thorough understanding of these effects is important for the accurate interpretation of simulation results and for enhancing the overall fidelity of micromagnetic modeling. In this work we focus on these errors introduced by using finite difference approximations in micromagnetic simulations.

Funded by EU Horizon 2020, grants 101152613 and 101135546.

MA 15.45 Tue 10:00 P1

Magnetization Reconstruction from Magnetic Field Measurements Using Physics-Informed Inverse Problems — •Alexander Setescak, Florian Bruckner, and Claas Abert — University of Vienna, Austria

Understanding the magnetization of topological spin textures is crucial for advancing spintronic applications. This work covers a physics-informed framework for reconstructing magnetization from high-resolution magnetic field measurements, such as those obtained via nitrogen-vacancy (NV) magnetometry. The approach leverages the micromagnetic equilibrium condition as a critical constraint in the inverse problem, ensuring the reconstructed magnetization satisfies the fundamental energy minimization principles.

The reconstruction process is formulated as an optimization problem, where a loss functional is designed to minimize discrepancies between measured and computed magnetic fields while imposing physical and regularization constraints. Efficient gradient computation is achieved through a combination of backpropagation algorithms and the adjoint method, enabling accurate and robust parameter optimization.

Preliminary results reveal detailed magnetization structures consistent with theoretical predictions and experimental observations. This demonstrates the potential of the proposed framework to investigate tailored magnetic configurations on the nanoscale, thereby laying the groundwork for future advancements in spintronic device engineering.

MA 15.46 Tue 10:00 P1

Synthetic Data Training Strategies for Magnetic Phase Classification — •Marcelo Arlego[1,2], Agustín Medina[1], and Carlos Lamas[1] — [1]Instituto de Física La Plata, La Plata, Argentina. — [2]Institute for Theoretical Physics TU-BS

In this work, we explore the potential of artificial neural networks trained with a synthetic catalogue of spin patterns, examining their ability to generalize and classify phases in complex models beyond the simplified training context.

Specifically, we investigate the transition from order to disorder in a diluted Ising model, a problem for which no exact solution exists, and where most current analytical and numerical techniques face significant difficulties.

Despite these obstacles, we used direct methods to achieve consistency in determining percolation densities and transition temperatures.

Our results suggest that a simple yet strategic training approach for neural networks can help in understanding complex physical phenomena, with potential applications beyond condensed matter physics.

MA 15.47 Tue 10:00 P1

Simulation of magnetoelastic mode filters for surface acoustic waves — •Bernhard Emhofer[1], Michael Karl Steinbauer[1], Peter Flauger[1], Matthias Volz[3], Matthias Küss[2], Stephan Glamsch[2], Manfred Albrecht[2], Hubert Krenner[3], and Claas Abert[1] — [1]University of Vienna — [2]University of Augsburg — [3]University of Münster

Surface acoustic wave (SAW) propagation critically depends on the waveguide geometry, with a key challenge being the independent excitation of specific mode types such as Rayleigh and shear modes.

In this study, we employ micromagnetic simulations, specifically the python library magnum.np [1], to explore a novel approach for selectively absorbing specific acoustic modes via magnetoelastic coupling. This coupling occurs through the excitation of spin waves in a thin magnetic film, layered on top of the waveguide. To achieve controlled mode filtering, the equilibrium magnetization is manipulated by varying the angle and strength of an external magnetic field. The distinct resonance configurations for Rayleigh and shear modes observed experimentally [2], enable their selective attenuation.

Simulations performed for a $LiNbO_3$ substrate with a 108 nm thick Ni film show that SAWs experience significant attenuation, with the maximum displacement at the surface reduced by around 70% after 13 wavelengths. These results demonstrate the potential of magnetoelastic interactions for precise mode filtering.

[1] F. Bruckner et al., Sci. Rep. 13, 12054 (2023).
[2] M. Küß et al., Phys. Rev. Appl. 15, 034046 (2021).

MA 15.48 Tue 10:00 P1

Revealing rich magnetic phases and novel spin-wave spectra in Orthorhombic perovskite TbCrO3: a frsfprinciples study — •Fengyi Zhou — Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, 999078, China

The experimental measurements have revealed the orthohombic perovskite $TbCrO_3$ crystal exhibits rich magnetic structures with temperature variation. Specifically, a long-range canted AFM state of Cr^{3+} ions is formed below $T_N^{Cr} = 157.9$ K. At a lower temperature (below $T_N^{Tb} \sim 7.7$ K), the Tb^{3+} ions exists a long-range antiferromagnetic (AFM) order. Furthermore, a weak competition between the FM and AFM interactions within the Cr^{3+} ions is observed at 15 K. Importantly, a strong coupling between the spin orders of the Cr^{3+} and Tb^{3+} ions is observed at 1.8 K. As the temperature decreases, the magnetic moment of Tb disappears first. Currently, in-depth theoretic research is appealing and urgently needed to explore these complex magnetic interactions, magnetic phase transition and spin wave spectra of $TbCrO_3$.

Based on the first-principles study, this study presents the entire magnetic landscape of $TbCrO_3$ including the magnetic ground state, equilibrium state, and excited state. Meanwhile, we clarified the detailed magnetic exchange mechanisms including the isotropic Heisenberg exchange and the antisymmetric Dzyaloshinskii-Moriya interaction, as well as single ion anisotropy. Finally, the spin wave spectrum considered adiabatic and temperature-dependent relationships is also evaluated.

MA 16: Topological Insulators (joint session MA/HL)

Time: Tuesday 14:00–15:15 Location: H16

MA 16.1 Tue 14:00 H16

Topological Hall effects on two-dimensional Archimedean lattices — •L.V. Duc Pham[1,2], Nicki F. Hinsche[2], and Ingrid Mertig[2] — [1]Fakultät für Chemie und Lebensmittelchemie, Technische Universität Dresden, Bergstraße 66c, 01062 Dresden, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle (Saale), Germany

Archimedean lattices are a family of tilings in which the two-dimensional plane is filled with different regular polygons while maintaining the vertices configuration. Kagome, the most famous member of the Archimedean lattices familiy, was studied extensively in a wide variety of theoretical works. Another lattice of this type, the snub square lattice, was also used as an approximant for quasi crystals [1]. The rich geometry of these systems gives rise to various unconventional nano ribbon edge configurations and therewith various possible topological edge states. In this work, we calculate the band structures of all 8 pure Archimedean lattices using a tight-binding method including s and p orbitals and study topological properties of these lattices, such as topological edge states, the $\mathbb{Z}_2$ invariance and the quantum spin Hall conductivity within the Kubo formalism [2].

[1] Roy, Sumalay, et al. "The Kepler tiling as the oldest complex surface structure in history: X-ray structure analysis of a two-dimensional oxide quasicrystal approximant." Zeitschrift für Kristallographie-Crystalline Materials 231.12 (2016): 749-755
[2] Sinova, Jairo, et al. "Spin hall effects." Reviews of modern physics 87.4 (2015): 1213-1260

MA 16.2 Tue 14:15 H16

Spin topology, spin-orbit coupling and entanglement — •Gunnar Felix Lange[1], Wojciech Jankowski[2] und Robert-Jan Slager[2,3] — [1]Department of Physics, University of Oslo, Norway — [2]TCM Group, Cavendish Laboratory, University of Cambridge, UK — [3]Theoretical Physics Group, University of Manchester, UK

Topological systems with time-reversal symmetry are of great theoretical and practical interest. Theoretically, such phases often rely on studying the topology in each spin sector separately, as in the spin Hall effect.

This requires identifying the spin degree of freedom in the band structure, which is not always straightforward in the presence of spin-orbit coupling. This field has received renewed interest in recent years, leading to the concept of spin topology.

In this talk, we will discuss some recent results on spin topological phases, with a particular focus on spin-orbit coupling and its interplay with entanglement.

MA 16.3 Tue 14:30 H16

Fractionally Charged Vortices at Quantum Hall/Superconductor

Interfaces — •Enderalp Yakaboylu and Thomas Schmidt — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg

We investigate interface states between a type-II *s*-wave superconductor (SC) and a Chern insulator describing an integer quantum Hall (QH) system. We find that an effective pairing interaction at this boundary gives rise to two emergent Abelian Higgs fields, representing the two paired electrons at the SC/QH interface, coupled to a gauge field that incorporates both Chern-Simons and Maxwell terms. We use this model to investigate the effect of magnetic flux vortices in the SC on the QH system. In particular, we find vortex solutions in which the Cooper pairs give rise to topological fractionally-charged vortices localized at the interface.

MA 16.4 Tue 14:45 H16

Local and Global Topological Characteristics of Local Magnetic Moments Coupled to Chern Insulators — •Devesh Vaish and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, University of Hamburg

A magnetic impurity, modelled as a classical spin and locally exchange coupled to a Chern insulator may cause in-gap bound states. Their nature can be very different depending on the (k-space) topological phase of the Chern insulator. Here we study several impurity spins coupled to a QWZ model and analyze, for different k-space topological phases, the additional "local" topological properties on the manifold of impurity-spin configurations (S-space). In case of $R > 1$ spins, the R-th spin-Chern number serves as a topological invariant on S-space. Varying the local exchange-coupling strength, we find local topological phase transitions and relate them to Fermi-energy crossings of in-gap states. In addition, we compute the first spin-Chern number for various physically motivated closed two-dimensional sub-manifolds of the full configuration space and relate those to the R-th spin-Chern number.

MA 16.5 Tue 15:00 H16

Non-relativistic linear Edelstein effect in noncollinear EuIn2As2 — •Adriana Nayra Alvarez Pari[1], Rodrigo Jaeschke Ubiergo[1], Atasi Chakraborty[1], Jairo Sinova[1,5], and Libor Smejkal[1,2,3,4] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz, Germany — [2]Max Plank Institute for the Physics of Complex Systems, Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]Institute of Physics, Academy of Sciences of the Czech Republic, Praha, Czech Republic — [5]Department of Physics, Texas A & M University, Texas, USA

Motivated by the ongoing interest in understanding the actual magnetic ground state of the promising axion insulator candidate EuIn2As2, we present here a spin symmetry analysis and *ab-initio* calculations, aiming to identify specific exchange-dominated physics that could offer insights into the current debate. We investigate two noncollinear coplanar magnetic orders reported in this compound: the *helical* and *broken-helical* phases [1]. Our symmetry analysis shows that magnetic-exchange alone results in the formation of an out-of-plane odd-wave order in momentum space in both phases. Additionally, we identify an in-plane g-wave order that emerges exclusively in the *broken-helical* phase, providing a distinguishing feature for this phase. Furthermore, we report a non-relativistic Edelstein effect with a distinct out-of-plane polarized spin density that dominates over spin-orbit coupling effects.

[1] Pari, Nayra A. Álvarez, et al. "Non-relativistic linear Edelstein effect in non-collinear EuIn2As2." *arXiv:2412.10984* (2024)

MA 17: Micro- and Nanostructured Magnetic Materials

Time: Tuesday 14:00–15:00 Location: H18

MA 17.1 Tue 14:00 H18

Thin films of a dinuclear Fe^{2+} complex on HOPG: Spin-crossover studies using X-ray absorption spectroscopy — •Marcel Walter[1], Sebastien Elie Hadjadj[1], Clara Trommer[2], Jorge Torres[1], Jendrik Gördes[1], David Swerev[1], Christian Lotze[1], Chen Luo[3], Florin Radu[3], Felix Tuczek[2], Sangeeta Thakur[1], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin — [2]Institut für Anorganische Chemie, Christian-Albrechts Universität zu Kiel — [3]Helmholtz Zentrum Berlin for Materialien und Energie

The spin-crossover (SCO) properties of the dinuclear complex $[\{Fe(H_2B(pz)_2)_2\}_2\mu - (ac(bipy)_2)]$ deposited as (sub)-monolayer and thin film by an ultra-high-vacuum liquid-jet deposition technique on highly oriented pyrolytic graphite (HOPG) were studied by X-ray absorption spectroscopy. A comparison of the SCO properties of thin films and a dropcast sample indicates that the spin-switching capability of the thin films is lower due to substrate*molecule interactions. The similar switching properties of the dropcast sample as of a bulk powder sample confirm that the SCO properties are not affected by the presence of solvent necessary for deposition. The soft-X-ray-induced excited spin-state trapping (SOXIESST) effect is pronounced in all samples, although the light-induced high-spin (HS) fractions of the dropcast and the thin-film samples on HOPG are higher as compared to the HS fraction attained by SOXIESST, which confirms the sensitivity of the complex to light.

MA 17.2 Tue 14:15 H18

Magnetic Characterization of Antidot Arrays in NiFe Thin Films: Insights from Ferromagnetic Resonance and Micromagnetic Simulations — •Zeynep Reyhan Ozturk[1] and Fikret Yildiz[2] — [1]SESAME, Amman, Jordan — [2]Gebze Technical University, Kocaeli, Türkiye

Antidot arrays, patterned magnetic films with regular nonmagnetic holes, are gaining attention for their unique behaviors and applications in data storage and sensors [1]. These arrays modify magnetic properties by introducing stray field energy, enabling control over magnetic anisotropy and magnetization reversal [2].

Optimizing antidot size, spacing, and lattice symmetry allows precise control of switching fields, magnetoresistance, and spin-wave modes, making them ideal for advanced technologies [3]. Their dynamic behavior, particularly localized spin-wave modes, sets them apart from continuous films.

This study combines ferromagnetic resonance (FMR) and micromagnetic simulations to reveal the influence of antidot geometry on magnetic performance. Insights gained optimize thin-film properties for next-generation devices.

References:

1.Kwon et al., Phys. Rev. B, 2013.

2.Duine et al., Phys. Rev. B, 2007.

3.Park et al., J. Appl. Phys., 2015.

MA 17.3 Tue 14:30 H18

Effect of Ag addition on structure, morphology and magnetism of CoCrFeMnNi micro powders prepared by HEBM — •Emmanouil Kasotakis, Ivan Tarasov, Tatiana Smoliarova, Michael Farle, and Natalia Shkodich — Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, 47057 Germany

We fabricated (CoCrFeMnNi)-Agx (x=0; 2; 5; 10 wt.%) high entropy alloy nanocrystalline (~10 nm) microparticles which are paramagnetic at room temperature (Tc = 80 K) by a two-step high energy ball milling (HEBM) [1] process in Argon at 700/1400 rpm. An elemental powder blend of Co, Cr, Fe, Mn, Ni was milled for 60 min to produce single phase FCC Cantor alloy with a homogeneous distribution of the principal elements, followed by 10 min of HEBM with the addition of Ag. By varying the Ag concentration, we modified the morphology. For 2 and 5 wt.% Ag (Cantor + Ag) we find flake-like core shell particles, and for 10 wt.% Ag, we obtain round homogeneous particles, with a lattice expansion of the FCC phase. Annealing cycles up to 700 K in a magnetic field of 1 T magnetic field increased M at 9 T up to 2.5-fold (14 Am^2/kg) for homogeneous particles (x = 10 wt.%) and Hc up to 5-fold (41 kA/m) for core shell particles (x = 2 wt.%) at 310 K. We acknowledge DFG financial support (project ID: FA209/27-1).

[1] N.F. Shkodich, M. Spasova, M. Farle, et al. J. Alloys Compd. 816, 152611 (2020).

MA 17.4 Tue 14:45 H18

Fabrication and characterization of freestanding magnetic nanostructures for microwave to photon transduction —

•Matthias Grammer[1,2], Jonny Qiu[3], Sebastian Sailler[4], Sebastian T. B. Goennenwein[4], Matthias Althammer[1,2], Stephan Gepräg[1,2], Michaela Lammel[4], Eva Weig[3], and Hans Huebl[1,2] — [1]Walther-Meißner-Institut, BAdW, Garching, Germany — [2]School of Natural Sciences, TUM, Garching, Germany — [3]School of Computation, Information and Technology, TUM, Garching, Germany — [4]Department of Physics, University of Konstanz, Konstanz, Germany

Efficient transduction between microwave and optical photons is critical for quantum network applications. Engelhard et al. [1] proposed a trasduction scheme based on collective magnetic and elastic excitations as mediators between the microwave and the optical regime. Implementing this concept requires co-localization of microwave, magnetic and elastic excitations within a suspended microstructure resembling an optomechanical crystal (OMC). In this presentation we present our progress towards the fabrication of a OMC based on the ferrimagnetic insulator yttrium iron garnet (YIG). To realize freely suspendend structures we explore two fabrication strategies: (i) the structuring of grown YIG/SiO_x/GGG heterostructures and (ii) the integration of YIG on semiconductor substrates. We will report on fabrication aspects and the characterization of the resulting devices using e.g. scanning electron microscopy and magneto-optical Kerr effect measurements.

[1] F. Engelhardt et al., Phys. Rev. Applied 18, 044059 (2022).

MA 18: Functional Antiferromagnetism

Time: Tuesday 14:00–15:30 Location: H19

MA 18.1 Tue 14:00 H19

Switching of magnetic domains in a noncollinear antiferromagnet at the nanoscale — •Atul Pandey[1,2], Prajwal Rigvedi[1], Edouard Edouard[3], Jitul Deka[1], Jiho Yoon[1], Wolfgang Hoppe[2], 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 — [3]Max Planck Institute for Chemical Physics of Solids, Nothnitzer Straße 40, 01187 Dresden, Germany

Antiferromagnets that display very small stray magnetic field are ideal for spintronic applications. Of particular interest are non-collinear, chiral antiferromagnets of the type Mn_3X (X=Sn, Ge), which display a large magnetotransport response that is correlated with their antiferromagnetic ordering. The ability to read out and manipulate this ordering is crucial for their integration into spintronic devices. These materials exhibit a tiny unbalanced magnetic moment such that a large external magnetic field can, in principle, be used to set the material into a single antiferromagnetic domain. However, in thin films of Mn_3Sn, we find that such fields induce only a partial magnetic ordering. By detecting two orthogonal in-plane components of the magnetic order vector, we find that the non-switchable fraction has a unidirectional anisotropy. This also enables us to visualize switching along multiple easy axes in Mn_3Sn. Studying the switching at the nanoscale allows us to correlate the pining behavior to crystal grain boundaries in the Mn3Sn nanowire structures.

MA 18.2 Tue 14:15 H19

Understanding the role of spin non-conserving on magnon excitation — •Hebatalla Elnaggar — Sorbonne University, Paris, France

Conventional wisdom suggests that one photon that carries one unit of angular momentum (1h) can change the spin angular momentum of a magnetic site with one unit (*M* = *1h) at most following the selection rules. This implies that a two-photon process such as 2*3* resonant inelastic X-ray scattering (RIXS) can change the spin angular momentum of a magnetic system with a maximum of two units (*M* = * 2h). Herein we describe a triple-magnon excitation in *-Fe2O3 and various perovskite thin films, 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 due to spin non-conserving interactions.

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

MA 18.3 Tue 14:30 H19

Domain wall patterns in granular Cr_2O_3 thin films — •Igor Veremchuk[1], Oleksandr V. Pylypovskyi[1], Peter Rickhaus[2], Natascha Hedrich[3], Artem V. Tomilo[1], Tobias Kosub[1], Kai Wagner[3], Brendan Shields[3], Gediminas Seniutinas[2], Vicent Borras[2], Paul Lehmann[3], Liza Žaper[2], Paulina J. Prusik[1], Pavlo Makushko[1], René Hübner[1], Jüren Fassbender[1], Denis D. Sheka[4], Patrick Maletinsky[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V.,01328 Dresden, Germany — [2]Qnami AG, CH-4132 Muttenz, Switzerland — [3]University of Basel, Basel CH-4056, Switzerland — [4]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Cr_2O_3 provides possibility to control its magnetic order parameter by an external electric field rendering it a prospective material for spintronic applications. We developed a material model for granular thin Cr_2O_3 films. The coupling between the grains influences the equilibrium domain pattern due to pinning of antiferromagnetic domain walls at the grain boundaries. By the characterization of the experimentally measured domain patterns via fractal dimension, we determine the inter-grain exchange coupling [1]. In contrast to extended films, finite-size samples can be set into a single-domain state even via a zero-field cooling procedure. Such a sample should be small enough for the propagation of thermally driven domain walls through the energy landscape formed by grain boundaries [2].

[1] O. V. Pylypovskyi et al., Phys. Rev. Appl. 20, 014020 (2023).
[2] P. Rickhaus, O. V. Pylypovskyi et al., Nano Lett. 24, 13172 (2024).

MA 18.4 Tue 14:45 H19

Domain walls properties and spin-flop transition in Cr_2O_3 — •Paulina J. Prusik[1,2], Igor Veremchuk[1], Florin Radu[3], Andrey N. Anisimov[1], Pavlo Makushko[1], Georgy V. Astakhov[1], Sophie F. Weber[4], René Hübner[1], Nicola A. Spaldin[4], Kirill D. Belashchenko[5], Jürgen Fassbender[1,2], Denys Makarov[1], and Oleksandr V. Pylypovskyi[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V. — [2]Dresden University of Technology, 01062 Dresden, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany — [4]ETH Zürich, 8093 Zürich, Switzerland — [5]University of Nebraska-Lincoln, Lincoln, NE 68588, USA

A room-temperature magnetoelectric uniaxial antiferromagnet Cr_2O_3 is a prospective material for spintronics and fundamental research [1,2]. We derive a σ-model for Cr_2O_3 and show the presence of a symmetry-breaking term relevant for non-collinear magnetic textures. It couples the magnetic field with a gradient of the Néel vector. Analyzing quantum magnetometry images of antiferromagnetic domain walls, we can properly describe the material parameters of Cr_2O_3. Furthermore, this term results in lowering of the spin-flop field for thin films of Cr_2O_3 by a factor of two comparing with single crystals. This finding is confirmed by X-ray magnetic linear dichroism measurements.

[1] J. Han et al., Nat. Mater. 22 (2023) 684; He et al, Nat. El. (2024) [2] P. Makushko et al., Nat. Comm. 13, 6745 (2022); O.V. Pylypovskyi et al., Phys. Rev. Let. 132, 226702 (2024); S.F. Weber et al., Phys. Rev. Lett. 130, 146701 (2023)

MA 18.5 Tue 15:00 H19

Current pulse driven switching mechanisms in antiferromagnetic Mn_2Au — •Jonathan Blässer[1], Sonka Reimers[1], Yuran Niu[2], Evangelos Golias[2], Francesco Maccherozzi[3], Miriam Fischer[1], Guzmán Orero Gámez[1], Mathias Kläui[1], and Martin Jourdan[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]MAX IV Laboratory, Lund, Sweden — [3]Diamond Light Source, Chilton, Didcot, Oxfordshire, UK

In antiferromagnetic spintronics, reorientation of the staggered magnetization driven by current pulses can originate from different mechanisms. Investigating Mn_2Au, for longer pulses [Rei23] the thermal contribution is dominant. However, for pulses in the nanosecond range

Néel spin-orbit torque switching is demonstrated.

[Rei23] S.Reimers et al., Nat Commun. 14, 1861 (2023)

MA 18.6 Tue 15:15 H19

Amplifying the antiferromagnetic spin Seebeck effect through topological magnons — Feodor Svetlanov Konomaev and •Kjetil Magne Dørheim Hals — Department of Engineering Sciences, University of Agder, 4879 Grimstad, Norway

Topological magnons emerge as topologically protected spin wave states at the edges of magnets. Here, we theoretically explore how these surface states can be harnessed to amplify the spin Seebeck effect (SSE) in antiferromagnets (AFMs) interfaced with normal metals (NMs). Based on a microscopic model of a kagome AFM, we demonstrate that broken mirror symmetry, combined with the Dzyaloshinskii-Moriya interaction (DMI), drives the system into a topological phase hosting spin-polarized magnons at the boundaries. Notably, linear response calculations reveal that in AFM/NM heterostructures, the topological magnons exhibit strong coupling to the metals charge carriers, resulting in a substantial enhancement of the SSE. The relative contribution of the topological magnons is found to be 4-5 times greater than that of the trivial magnon bands. Moreover, our results show that this enhancement is highly sensitive to the strength of the DMI.

MA 19: Magnetic Imaging and Sensors

Time: Tuesday 14:00–15:15 Location: H20

MA 19.1 Tue 14:00 H20

Green synthesis of R-type hexagonal ferrite magnetic nanoparticles and their electrochemical sensor for levofloxacin — •SAJJAD HUSSAIN — Centre of Excellence in Solid State Physics, University of the Punjab, Lahore

The usage of Levofloxacin (LEV) has increased in recent years for the treatment of bacterial infections in both human and veterinary fields. In this context, there has been a significant demand for the development of a highly sensitive and cost-effective approach to LEV quantification. In this study, R-type hexagonal ferrite nanoparticles (SrSn2Fe4O11-NPs) were prepared by an auto-ignition methodology and various analytical techniques were used for the material characterization, including X-ray diffraction (XRD), Field emission scanning electron microscopy (FE-SEM), X-ray photoelectron spectroscopy (XPS), Brunauer Emmett and Teller (BET) analysis, dynamic light scattering (DLS), and vibrating sample magnetometer (VSM) analysis. The characterization confirmed that the prepared material has a crystalline structure single-phase with a crystalline size of 35.02 nm. The R-type hexagonal ferrite nanoparticles were immobilized on a glassy carbon electrode (GCE) by a simple drop-casting approach to developing an efficient electrochemical sensor (SrSn2Fe4O11-NPs) for sensitive and selective LEV detection through an extended concentration range (0.06 * 10*6 to 170 * 10*6 M) and a low detection limit of (41.5nM). The developed sensor was applied successfully to quantitatively determine LEV in clinical samples and pharmaceutical preparations with excellent recoveries from 95.2 to 102.5 %.

MA 19.2 Tue 14:15 H20

Signatures of Berezinskii-Kosterlitz-Thouless transitions in magnetic films in Nitrogen Vacancy Magnetometry — •Mark Potts and Shu Zhang — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Nitrogen vacancy magnetometry provides sensitive measurements of the correlation functions of magnetic degrees of freedom in a material. Recent experiments have applied this technique in the study of two dimensional thin films, candidates for realising the topological Berezinskii-Kosterlitz-Thouless phase transition. We present calculations of frequency dependent relaxation rates for nitrogen vacancy centres coupled to an XY-type magnetic film, and identify features characteristic of the transition to quasi-long ranged order, and show that algebraic spin correlations are inherited by the relaxation rate as a temperature dependent power-law at low frequencies.

MA 19.3 Tue 14:30 H20

Development of an Ultra High Vacuum and Low Temperature Scanning NV Magnetometer — •Sandip Maity[1], Ricardo Javier Peña Román[1], Dinesh Pinto[1,3], Klaus Kern[1,3], and Aparajita Singha[2,1] — [1]Max Planck Institute for Solid State Research, Stuttgart, German — [2]Technische Universität Dresden, Dresden, Germany — [3]Institut de Physique, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

The nanoscale spatial resolution and calibration-free quantifiable magnetic field measurement capabilities of nitrogen-vacancy (NV) centers have enabled us to investigate the properties of magnetic spin textures with high magnetic sensitivity through scanning probe microscopy across a wide range of temperatures and pressure. I will be discussing the development of a scanning probe magnetometer capable of imaging magnetic nanostructures under ultra-high vacuum and low temperature. Moreover, we have integrated commercial NV tips with a home-built tip holder equipped with an AFM amplifier and microwave excitation on the tip (not on the sample), allowing us to have a magnetic image of any sample region without restriction. To exploit the quantifying nature of NV magnetometry using Optically Detected Magnetic Resonance, a coherent microwave (MW) delivery to the probe is mandatory. I will also discuss different means of delivering MW to the NV probes through different designs of the tip holders and how effective they are in coherently manipulating the NV spin states.

MA 19.4 Tue 14:45 H20

On-surface Spin Characterization using Shallow NV Centers in Diamond — •Olga Shevtsova[1,2], Atharva Paranjape[2], Lisa Ebo[2,3], Bernhard Putz[4], Ulrich Ziener[4], Marvin Grünhagen[5], Rainer Herges[5], and Aparajita Singha[1,2] — [1]Technische Universität Dresden, Dresden, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Universität Konstanz, Konstanz, Germany — [4]Universität Ulm, Ulm, Germany — [5]Christian-Albrechts-Universität zu Kiel, Kiel, Germany

As interest in quantum systems surges due to their potential applications in quantum computing, information storage, and sensing, molecular spins emerge as promising candidates for these technologies. Unlike conventional systems such as superconducting qubits and trapped ions, molecular spins offer unique advantages in stability, tunability, and scalability. However, key challenges remain in assessing their coherent properties, which are crucial for practical application. Existing techniques face limitations in terms of environmental requirements, complexity, and invasiveness. In this context, Nitrogen-Vacancy (NV) centers in diamonds emerge as a highly suitable solution, as they can operate at a wide range of temperatures and provide non-invasive optical readout. This study aims to leverage on the capabilities of NV-center-based sensors to probe the coherent properties of molecular spins, thus providing insights into their viability as stable and controllable components for future quantum technologies.

MA 19.5 Tue 15:00 H20

Imaging magnetic vortices in a van der Waals magnet at room temperature with scanning NV magnetometry — •Carolin Schrader[1], Elias Sfeir[1], Mário Ribeiro[2], Giulio Gentile[2], Alain Marty[2], Céline Vergnaud[2], Frédéric Bonell[2], Isabelle Robert-Philip[1], Matthieu Jamet[2], Vincent Jacques[1], and Aurore Finco[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Université Grenoble Alpes, CEA, CNRS, IRIG-SPINTEC, Grenoble, France

Two-dimensional van der Waals (vdW) magnets have gained significant attention for their potential application in spintronics, however, this would require room temperature magnetism and large-scale fabrication. Recently, ferromagnetic order at room temperature has been demonstrated in thin Fe_5GeTe_2 grown by Molecular Beam Epitaxy (MBE). Here, we employ scanning NV magnetometry to quantitatively image the magnetic texture in MBE-grown Fe_5GeTe_2 at the nanoscale. We use the single spin of the nitrogen-vacancy (NV) defect in diamond to investigate the effect of patterning on the magnetic order and demonstrate the stabilisation of magnetic vortices in various micron-sized structures at room temperature. Upon application of an external magnetic field of a few mT we obtain a single ferromagnetic domain in these structures, which allows us to extract a saturation magnetisation of about 160 kA/m. Our results show the role of con-

finement for the stabilisation of complex magnetic structures in 2D magnets and highlight the potential of the room temperature vdW magnet Fe_5GeTe_2 for applications in spintronics.

MA 20: Magnonics II

Time: Wednesday 9:30–13:15 Location: H16

MA 20.1 Wed 9:30 H16

Wavenumber-dependent magnetic losses in YIG-GGG heterostructures at millikelvin temperatures — •David Schmoll[1], Andrey A. Voronov[1], Rostyslav O. Serha[1], Denys Slobodianiuk[2], Khrystyna Levchenko[1], Claas Abert[1], Sebastian Knauer[1], Dieter Suess[1], Roman Verba[2], and Andrii V. Chumak[1] — [1]University of Vienna, Vienna, Austria — [2]V.G. Baryakhtar Institute of Magnetism of the NAS of Ukraine, Kyiv, Ukraine

With its low magnetic damping, the ferrimagnet yttrium iron garnet (YIG), grown on gadolinium gallium garnet (GGG), is the most promising material for magnon based quantum technologies, wich demand long decoherence times. While such samples are already well established at room temperature, further knowledge needs to be acquired at millikelvin temperatures, due to the paramagnetic character of the GGG substrate. We report on propagating spin-wave spectroscopy studies at temperatures between 4 K to 26 mK and the recorded change of the dissipation rate. Additionally, we compute the dispersion and the dissipation rate of the layered YIG-GGG magnetic system quasi-analytically and with micromagnetic simulations, allowing us to investigate the magnon losses with respect to wavenumber. Contrary to room temperature, we observe a significant increase of the magnetic losses with k at cryogenic temperatures, introduced by the dipolar coupling between the ferrimagnetic YIG film and the partially magnetized GGG substrate. Our theoretical calculations predict a steady decrease of the dissipation for short-wavelength exchange magnons.

MA 20.2 Wed 9:45 H16

Exchange enhanced switching in quantum antiferromagnets with dephasing and relaxation — •Asliddin Khudoyberdiev and Götz S. Uhrig — Condensed Matter Theory, TU Dortmund University, Otto-Hahn-Straße 4, 44221 Dortmund, Germany

One requirement for ultrafast storage devices is that they can be operated in the terahertz (THz) regime. Suitable candidates are antiferromagnets because of their characteristic frequencies range. The efficient control of their order is the focus of a plethora of current studies. Recently, we established a quantum approach, time-dependent Schwinger boson mean-field theory, to reverse the sublattice magnetization in anisotropic quantum antiferromagnets by means of external static and oscillating magnetic fields [1,2]. We also showed that the exchange enhancement for staggered control fields persists on the quantum level so that significantly lower fields are sufficient to switch the order [3]. Our quantum theory incorporates dephasing, i.e., the destructive interference of the contributions of all spin modes at their respective frequencies, which results in a slow, non-exponential decrease of the oscillations after the switching [2,3]. This must be distinguished from spin-lattice relaxation which induces faster decay of oscillations. Our methodological progress including Lindblad dissipators allows us to address the differences between dephasing and spin-lattice relaxation in the switching processes. [1] K. Bolsmann, A. Khudoyberdiev, and G. S. Uhrig, PRX Quantum 4, 030332 (2023) [2] A. Khudoyberdiev and G. S. Uhrig, Phys. Rev. B 109, 174419 (2024) [3] A. Khudoyberdiev and G. S. Uhrig, arXiv:2407.00472.

MA 20.3 Wed 10:00 H16

Non-linear processes in YIG based spin-wave transducers — •Matthias Wagner, Felix Kohl, Björn Heinz, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Spin waves are considered as promising candidates for the realization of future signal processing devices. Due to their fundamental equation of motion, spin-wave dynamics are inherently non-linear. For the practical application of spin-wave based devices, this non-linear nature can either be a perspective or a challenge, depending on the desired use case. Therefore, a systematic study on the impact of non-linear dynamics on a potential spin-wave based device is instructive. For this purpose, spin-wave transducers patterned on yttrium iron garnet (YIG) films are investigated. Using micro-focused and time-resolved Brillouin light scattering spectroscopy, the power-limiting non-linear processes as well as their scattering dynamics are analysed. The characterization is complemented by propagating spin-wave spectroscopy measurements to study the corresponding impact of the non-linear processes on the output of the spin-wave transducers. The results of this work provide an important foundation to develop new concepts of signal processing devices using spin waves. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 20.4 Wed 10:15 H16

Higher Order Resonances in Periodically Driven Magnon Systems — •Jan Mathis Giesen, Alexandre Abbass Hamadeh, Philipp Pirro, Imke Schneider, and Sebastian Eggert — RPTU, Kaiserslautern, Germany

We analyze resonant excitations of ferromagnetic magnons via microwave pumping below the threshold frequency using Floquet theory. A special feature of parameteric resonance is the possibility to create magnons with higher energy than the driving frequency, which allows for new tuning possibilities. We develop a theoretical framework that analytically predicts the region of resonances and resonance thresholds in thin films of ferro- and ferri-magnetic materials as a function of damping, amplitude and frequency. The results are compared with micomagnetic simulations.

MA 20.5 Wed 10:30 H16

SAW-Induced Spin Wave Excitation in Ferromagnetic Epitaxial Thin Films — •Alfons Georg Schuck, Sebastian Kölsch, and Michael Huth — Institute of Physics, Goethe University, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

Surface acoustic wave (SAW) excitation of spin waves in ferromagnetic thin films has recently gained significance due to the potential for the realization of novel microwave devices and applications in magnonics. So far, SAW excitation has commonly been accomplished by use of piezoelectric substrate materials, such as $LiNbO_3$, on top of which the ferromagnetic thin film is deposited [1]. This approach has severe limitations with regard to studying SAW-spin wave coupling effects in epitaxial magnetic thin films. For epitaxy to occur, selected substrate materials and crystal orientations have to be used; and these substrate materials tend not to be piezoelectric.

Here we show how textured piezoelectric AlN thin film transducer structures can be fabricated on different substrate materials by means of reactive RF sputtering. By proper selection of the material for the interdigital transducer electrode structures and standard UV lithography, the frequency range up to about 3 GHz becomes available for spin wave excitation. Selected examples of SAW-induced spin wave excitation in epitaxial magnetic thin films are presented and compared to results obtained on Nickel thin films as commonly used reference material. Complementary simulations of the SAW attenuation are shown and the influence of the magnetic anisotropy is described.

[1] M. Weiler et. al., Phys. Rev. Lett. **106**, 117601, **2011**

MA 20.6 Wed 10:45 H16

Integrated hybrid magnonic-spintronic system for tunable broadband signal filtering and microwave generation — •Abbas Koujok[1], Abbass Hamadeh[1,2], Leandro Martins[3], Felix Kohl[1], Björn Heinz[1], Ricardo Ferreira[4], Alex Jenkins[4], Ursula Ebels[3], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Université Paris-Saclay, Centre de Nanosciences et de Nanotechnologies, CNRS, 91120, Palaiseau, France — [3]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, IRIG, Spintec, Grenoble, France — [4]International Iberian Nanotechnology Laboratory (INL), 4715-31 Braga, Portugal

Non-conventional beyond-the-state-of-the-art signal processing schemes require parallelism, scalability, robustness and energy efficiency to meet the demands of complex data-driven applications.

Magnonic and spintronic circuits are potential candidates that can aid in fulfilling these requirements. Hereby, an experimental proof-of-concept for a novel hybrid magnonic-spintronic device is proposed. Using spintronic auto-oscillations, this device can generate a broad, GHz-wide RF signal and filter this signal in a selective and tunable manner using a magnonic circuit. This research is funded by the European Research Council within the Starting Grant No. 101042439 "CoSpiN" and by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - TRR 173-268565370 (project B01). U.E. acknowledges financial support from CEA PTC-21ID26 MINOS.

MA 20.7 Wed 11:00 H16

Spatially Resolved Investigation of Spin Wave frequency Multiplication — •Roméo Beignon[1], Chris Körner[2], Rouven Dreyer[2], Georg Woltersdorf[2], Vincent Jacques[1], and Aurore Finco[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

Interactions between spin waves and magnetic textures offer promising tools for designing magnonic devices. Among new developments, a frequency multiplication phenomenon has been observed in permalloy microstructures [1]. This generation of a high harmonic frequency has been observed using magnetic resonance measurements on NV center ensembles.

Here, we use scanning NV-center microscopy to investigate this phenomenon further. Our aim is to obtain maps of the harmonic generation with a spatial resolution of about 50 nm, and to correlate them with the magnetic state of the Py microstructures (edges, domain walls, ...).

Our results show that we can detect the spin wave frequency comb with a single NV center in a scanning probe tip. Furthermore, we are able to spatially map the effect of each harmonic on the NV center separately, revealing a non-trivial behavior. These measurements are a first step towards the understanding of the interplay between the non-linear process that generates the harmonics and the magnetic texture.

[1] Köerner et al., Science 375. 1165-1169 (2022)

15 min. break

MA 20.8 Wed 11:30 H16

Tayloring spin-wave transducers for integrated RF application — •Felix Kohl, Björn Heinz, Matthias Wagner, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Current advances in magnonics are increasingly targeted at improving the functional applicability of integrated magnonic devices. Despite the widespread use of transducers based on dynamic Oersted field excitation, there are still inefficiencies due in part to a discrepancy between the scientific understanding of magnetic responses and the technical requirements for practical implementation. Using propagating spin-wave spectroscopy, we investigated spin-wave transducers patterned on yttrium-iron-garnet (YIG) films, demonstrating the capability to tailor transducer characteristics, such as non-reciprocity towards a desired use case. Supported by a modelling approach, our measurements provide a useful framework for designing efficient, application-specific transducers and pave the way for integrated and standalone RF devices such as isolators and filters. This work is an important step towards scalable, energy-efficient magnonic application and demonstrates the potential of magnonics to become a future technology. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No. 101070536,MandMEMS).

MA 20.9 Wed 11:45 H16

Investigation of parallel parametric signal amplification in YIG nanostructures — •Akira Lentfert, Björn Heinz, David Breitbach, Burkard Hillebrands, and Philipp Pirro — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, 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 and sensitive 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 microscopic metallic waveguides has already been demonstrated in previous works. In this work, we focus on the phase dependence of the parallel parametric amplification processes in Damon-Eschbach (DE) geometry in yttrium iron garnet (YIG) nanowaveguides for propagating spin waves. 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 study the phase-dependent 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 20.10 Wed 12:00 H16

Nanoscaled Spin-Wave Frequency Selective Limiter (FSL) for 5G Technology — •Kristýna Davídková[1], Khrystyna Levchenko[1], Florian Bruckner[1], Roman Verba[2], Fabian Majcen[1], Qi Wang[3], Carsten Dubs[4], Vincent Vlaminck[5], Jan Klíma[6], Michal Urbánek[6], Dieter Suess[1], and Andrii Chumak[1] — [1]University of Vienna, Austria. — [2]Institute of Magnetism, Ukraine. — [3]School of Physics, China. — [4]INNOVENT e. V. Technologieentwicklung, Germany. — [5]IMT Atlantique, France — [6]CEITEC BUT, Czech Republic

Power limiters are essential devices in radio frequency communications systems to protect the input channels from large incoming signals. Nowadays-used semiconductor limiters suffer from high electronic noise and switching delays when approaching the GHz range, which is crucial for the modern generation of 5G communication technologies aiming to operate at the EU 5G high band (24.25-27.5 GHz). The proposed solution is to use ferrite-based Frequency Selective Limiters (FSLs), which maintain their efficiency at high GHz frequencies, although they have only been studied at the macroscale so far. We demonstrate a proof of concept of nanoscale FSLs based on spin-wave transmission affected by four-magnon scattering phenomena in a 97-nm-thin YIG film. Spin waves were excited and detected using coplanar waveguide transducers of the smallest feature size of 250 nm. The FSLs are tested in the frequency range up to 25 GHz, and the key parameters are extracted (power threshold, power limiting level, insertion losses, bandwidth) for different SW modes and transducer lengths.

MA 20.11 Wed 12:15 H16

Uniaxial strain response of antiferromagnetic magnons — •Manuel Knauft, Arthur von U.-S. Schwark, Yiran Liu, Lichen Wang, Sajna Hameed, Matteo Minola, and Bernhard Keimer — Max Planck Institute for Solid State Research, Stuttgart, Germany

With the suggested paradigm shift away from conventional transistors towards lower loss devices, magnonics has attracted considerable attention in recent years. Generation, manipulation and detection of magnons are prerequisites for successful integration into microstructured chips. We will present ideas and results of using uniaxial strain to control magnon behavior in perovskite antiferromagnets. In particular, recent work on iridates has shown that the magnon energy can be varied by as much as 40 % with small uniaxial strain of about 0.1 % [1]. Building on those findings, we discuss alternative approaches. Furthermore, through spatially inhomogeneous strain environments, we will also demonstrate ideas of guiding magnons as investigated using finite element simulation and confocal Raman scattering.

[1] Kim *et al.*, Nat. Commun. **13**, 6674 (2022)

MA 20.12 Wed 12:30 H16

cavity-enhanced optical manipulation of Antiferromagnetic magnon-pairs — •Tahereh Parvini — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meißner-Str.8, 85748 Garching, Germany

The optical manipulation of magnon states in antiferromagnets (AFMs) holds the potential for advancing AFM-based computing devices. In particular, two-magnon Raman scattering processes are known to generate entangled magnon-pairs with opposite momenta. We propose to harness the dynamical backaction of a driven optical cavity coupled to these processes, to obtain steady states of squeezed magnon-pairs, represented by squeezed Perelomov coherent states. The system's dynamics can be controlled by the strength and detuning of the optical drive and by the cavity losses. In the limit of a fast (or lossy) cavity, we obtain an effective equation of motion in the Perelomov representation, in terms of a light-induced frequency shift and a collective induced dissipation which sign can be controlled by the detuning of the drive. In the red-detuned regime, a critical power threshold defines a region where magnon-pair operators exhibit squeezing, a resource for quantum information, marked by distinct attractor points. Beyond this threshold, the system evolves to limit cycles of magnon-pairs. In contrast, for resonant and blue detuning regimes, the magnon-pair dynamics exhibit limit cycles and chaotic phases, respectively, for low and high pump powers. Observing strongly squeezed states, auto-oscillating limit cycles, and chaos in this platform presents opportunities for future quantum technologies.

MA 20.13 Wed 12:45 H16

Predicting the future with magnons — •Zeling Xiong[1,2], Christopher Heins[1,2], Katrin Schultheiss[1], Helmut Schultheiss[1], Thibaut Devolder[3], and Joo-Von Kim[3] — [1]Helmholtz-Zentrum Dresden Rossendorf, Germany — [2]Technische Universität Dresden, Germany — [3]Centre de Nanosciences et de Nanotechnologies, ClderNRS, Université Paris-Saclay, France

The Mackey-Glass (MG) time series data describes how density of mature circulating cells change over time using time delayed differential equations. This is a standard problem to test the performance of physical reservoirs. Here, we used different magnon reservoir systems to carry out such time series prediction task. By connecting several reservoirs together we increase the reservoir depth which yielded very accurate long-time future prediction.

MA 20.14 Wed 13:00 H16

Dynamic Control of Spin-Wave Propagation for Advanced Computing Applications — •Dmitrii Raskhodchikov[1], Kirill Nikolaev[2], Jannis Bensmann[1], Rudolf Bratschitsch[1], Vladislav Demidov[2], Sergey Demokritov[2], and Wolfram Pernice[1,3] — [1]Institute of Physics and Center for Nanotechnology (CeNTech), Muenster, Germany — [2]Institute of Applied Physics, Muenster, Germany — [3]Kirchhoff-Institute for Physics, Heidelberg, Germany

Spin waves, collective excitations of electron spins in magnetic materials, have attracted significant interest for spin-wave and neuromorphic computing applications. A key challenge in utilizing spin waves for these technologies is achieving precise control over their propagation. This study investigates methods to regulate spin-wave dynamics by manipulating parameters like the external magnetic field, excitation frequency, and the integration of external memory elements, including phase-change materials.

Our results show that varying the external magnetic field influences the dispersion relation of spin waves, allowing for tunable propagation velocities and wavelengths. Adjusting the excitation frequency enables selective excitation of spin-wave modes with desired properties. Furthermore, incorporating phase-change materials allows for dynamic modulation of spin-wave propagation through localized changes in magnetic anisotropy or damping. This approach provides a foundation for adaptive control mechanisms essential for spin-wave-based information processing.

MA 21: Frustrated Magnets I

Time: Wednesday 9:30–12:45 Location: H18

MA 21.1 Wed 9:30 H18

Ab-initio exploration of complex magnetism of frustrated Mn and Cr films on hexagonal metallic surfaces — •Selcuk Sözeri[1,2] and Samir Lounis[2,1] — [1]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

We employ ab initio first-principles simulations to explore the complex magnetic behavior in antiferromagnetic (AFM) systems. Specifically, we investigate Mn films on an Ag(111) substrate, where spin-polarized STM experiments established Néel order as the ground state for a single Mn layer [1,2] in contrast to previous predictions. Our focus extends to the interplay of Heisenberg exchange interactions, leading to magnetic frustration, and higher-order magnetic interactions when increasing the thickness of Mn films, which can host complex three-dimensional AFM spin-textures. Additionally, we examine the magnetic properties of multiple AFM Cr layers deposited on a PdFe bilayer supported by an fcc Ir(111) substrate. Instead of being in a Néel state, a single Cr layer prefers a row-wise AFM state, which hosts single and catenated intrinsic AFM skyrmions [3]. For thicker Cr films, we monitor the emergence of new topological magnetic objects.

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

– [1] Gao, et al., PRL 101, 267205 (2008); [2] Sözeri et al., submitted (2024); [3] Aldarawsheh et al., Nat. Commun.13, 7369 (2022); Front. Physics. 11, 335 (2023).

MA 21.2 Wed 9:45 H18

Dilatometry studies on the spin supersolid candidate materials $K_2Co(SeO_3)_2$ and $Rb_2Co(SeO_3)_2$ — •Erik Walendy[1], Kwangwoo Shin[2], Jae-Ho Chung[2], Kwang-Yong Choi[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, Korea University, Seoul 02841, Korea

The layered triangular lattice material $K_2Co(SeO_3)_2$ has recently attracted attention due to the presence of a high-field spin supersolid phase between 18 and 21 T, at 2 K [1]. We report high-resolution capacitance dilatometric studies on single crystals of $K_2Co(SeO_3)_2$ and $Rb_2Co(SeO_3)_2$. Pronounced anomalies in thermal expansion and magnetostriction measurements at the phase boundaries imply significant magnetoelastic coupling. We obtain the uniaxial strain dependencies of the field-induced phases and construct the magneto-elastic phase diagrams.

[1] T. Chen et al. arXiv:2402.15869 (2024).

MA 21.3 Wed 10:00 H18

NMR Study of the $S = 1/2$ 1D Heisenberg Antiferromagnetic Chain $Cu(C_6H_8N_2)ClBr$ — •Marlis Schuller[5], Monika Jawale[1], Avinash Mahajan[1], Sanjay Bachhar[1], Saikat Nandi[1], Rahul Kumar[2], Athinarayanan Sundaresan[2], John Wilkinson[3], Rabindranath Bag[4], Sara Haravifard[4], Norbert Büttgen[5], Thomas Gimpel[5], and István Kézsmárki[5] — [1]Department of Physics, IIT Bombay, IN — [2]CPMU, JNCASR, IN — [3]ISIS Facility, STFC Rutherford Appleton Laboratory, GB — [4]Department of Physics, Duke University, US — [5]EPV, Institute of Physics, University of Augsburg, DE

$Cu(C_6H_8N_2)ClBr$ is a possible candidate for realising the frustration-induced quantum spin-liquid phase, as proposed in a recent theoretical study by Uematsu *et al.* (JPSJ **90**, 124703 (2021)) on the random-bond $S = 1/2$ Heisenberg antiferromagnet on the zigzag chain. Based on μSR and bulk susceptibility data, it does not display any long-range order down to 88 mK. Mixing chlorine and bromine may generate randomness in the nearest-neighbour exchange necessary to satisfy the criteria from the aforementioned proposal. We investigated this compound by ^{1}H-NMR, and determined the spin-lattice relaxation rate $1/T_1(T)$ to probe low-energy excitations. Our study revealed a discontinuity in the relaxation rate at a characteristic temperature of approximately 2.5 K, where anomalies were observed in the specific heat and μSR experiments. These experimental results imply the emergence of a dimerised ground state.

MA 21.4 Wed 10:15 H18

Geometric design of frustrated magnetic textures in ferrotoroidal spin chains — •Oleksandr V. Pylypovskyi[1], Enrico Di Benedetto[2], Carmine Ortix[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]Università degli Studi di Palermo, 90123 Palermo, Italy — [3]Università di Salerno, IT-84084 Fisciano (SA), Italy

Design of geometric shapes in magnetic nanosystems provides a possibility to tune their magnetic responses [1] and even enable multiferroicity by a finite geometry-driven toroidal moment [2]. Here, we consider the effects of ring-like geometries with a constant torsion on properties of 3D ferro- (FM) and antiferromagnetic (AFM) spin chains. Their magnetic state is primarily determined by the knots in geometry with a high curvature, which corresponds to a localized geometry-driven Dzyaloshinskii–Moriya interaction (DMI). This DMI favors the twist of the order parameter at the knot. For the AFM chains with even and odd number of spins, the number of knots in their geometry allows designing the ground-state magnetic texture characteristic either for the spin system with or without geometric frustration. While the FM chains with the easy tangential axis of magnetization host a large toroidal moment for the whole sample, AFM hard-axis chains split into toroidal domains by geometric knots. To conclude, the localized geometry-driven DMI offers a possibility to design frustrated magnetic textures in spin chains.

[1] D. Makarov et al., Adv. Mater. 34, 2101758 (2022). [2] C. Ortix, J. van den Brink, Phys. Rev. Research, 5, L022063 (2023).

MA 21.5 Wed 10:30 H18

High-temperature expansion of dynamical spin correlator: Dyn-HTE — •Ruben Burkard[1], Benedikt Schneider[2,3], and Björn Sbierski[1] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 Munich, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

Currently, there is a scarcity of theoretical methods to calculate dynamical correlation functions at finite temperatures in frustrated spin systems. To address this challenge, we extend the well-established method of high-temperature expansion to the dynamical two-point Matsubara Green's function, which we calculate to high order in perturbation theory. We consider Heisenberg models with one coupling constant J, arbitrary spin length, and without external magnetic field. We use resummation techniques to extrapolate our results to temperatures down to about $T \approx 0.2J$. Our method also gives an analytical expression for the frequency dependence, enabling analytical continuation to real frequencies. Using the dynamical information of the Matsubara correlator, we aim to study spin-liquid phases with this approach in the future.

MA 21.6 Wed 10:45 H18

Pseudo-Majorana Functional Renormalization for Frustrated XXZ-Z Spin-1/2 Models — Ruben Burkard[1], Benedikt Schneider[2], and •Björn Sbierski[1] — [1]Universität Tübingen — [2]LMU München

The numerical study of high-dimensional frustrated quantum magnets remains a challenging problem. Here we present an extension of the pseudo-Majorana functional renormalization group to spin-1/2 XXZ type Hamiltonians with field or magnetization along spin-Z direction at finite temperature. We consider a U(1) symmetry-adapted fermionic spin representation and derive the diagrammatic framework and its renormalization group flow equations. We discuss benchmark results and application to two anti-ferromagnetic triangular lattice materials recently studied in experiments with applied magnetic fields: First, we numerically reproduce the magnetization data measured for CeMgAl11O19 confirming model parameters previously estimated from inelastic neutron spectrum in high fields. Second, we showcase the accuracy of our method by studying the thermal phase transition into the spin solid up-up-down phase of Na2BaCo(PO4)2 in good agreement with experiment.

15 min. break

MA 21.7 Wed 11:15 H18

NMR study of the field-induced magnetic states in Cu-based mineral $Cu_2(OH)_3NO_3$ — •Yoshihiko Ihara[1], Issei Niwata[1], Aswathi M. Chakkingal[2], Dmytro Inosov[2], and Darren Peets[2] — [1]Hokkaido University, Sapporo, Japan — [2]TU Dresden, Dresden, Germany

Magnetic ground states are stabilized at low temperature by minimizing the energy costs for magnetic moments interacting with each other. When the interactions compete by geometrical frustration in the case of a non-bipartite lattice or by the bond-dependent sign of interactions, the magnetic ground state cannot be easily selected and the perturbation by external fields can modify the ground state introducing a nontrivial magnetic state with intriguing properties. Here, we focus on the Cu-based mineral rouaite, $Cu_2(OH)_3NO_3$, in which $S = 1/2$ Cu^{2+} spins construct both ferromagnetic (FM) and antiferromagnetic (AFM) chains in a unit cell. Competing FM and AFM interactions result in complicated field-temperature phase diagram with at least three different magnetic states. We study the magnetic structure and the low-energy magnetic excitations by measuring the NMR spectra and the nuclear spin-lattice relaxation rate. The low-field magnetic structure is identified and compared with the results of neutron diffraction measurements. We will also discuss the external magnetic field effect on the magnetic ground state from the results of NMR measurements at higher magnetic fields.

MA 21.8 Wed 11:30 H18

Magnetic Properties of the Frustrated Cu-based Quantum Magnets Posnjakite, Kobyashevite, and Ktenasite — Kaushick K. Parui[1], Anton A. Kulbakov[1], Roman Gumeniuk[2], Sergey Granovsky[1], Dmytro S. Inosov[1], and •Darren C. Peets[1] — [1]IFMP, TU Dresden, Germany — [2]IEP, TU Bergakademie Freiberg, Germany

Posnjakite, kobyashevite, and ktenasite are copper hydroxide sulphates in which the magnetic copper sites are arranged in distorted-triangular planes. Such a magnetic sublattice is expected to lead to strong geometric frustration, which can produce exotic magnetic order. We report the synthesis of all three materials and the results of our investigations into their low temperature magnetic properties by magnetization, specific heat, and diffraction. All three compounds indeed exhibit low magnetic transition temperatures with high frustration factors, confirming that frustration plays a key role in selecting their magnetic ground states.

MA 21.9 Wed 11:45 H18

The role of quantum fluctuations in rare-earth pyrochlore oxides — •Lasse Gresista[1], Daniel Lozano-Gómez[2], Simon Trebst[1], and Yasir Iqbal[3] — [1]Institute for Theoretical Physics, University of Cologne — [2]Institut fur Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universitat Dresden — [3]Department of Physics and Quantum Center for Diamond and Emergent Materials (QuCenDiEM), Indian Institute of Technology Madras, Chennai, India

Rare-earth pyrochlore oxides provide a rich platform for exploring exotic magnetic phenomena, ranging from the highly degenerate spin-ice states governed by emergent gauge theories in $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$, to order-by-disorder effects in $Er_2Ti_2O_7$, multi-phase magnetism in $Yb_2Ti_2O_7$, and the ongoing quest to realize a quantum spin liquid state in experiment. Many of these materials are well described by localized spin-$\frac{1}{2}$ moments on a pyrochlore lattice coupled via anisotropic interactions. While the classical limit of this model has been extensively studied, a full quantum mechanical treatment remains challenging. In this work, we investigate the general spin-$\frac{1}{2}$ Hamiltonian using a pseudo-fermion functional renormalization group approach, which incorporates quantum fluctuations beyond mean-field theory. Our results reveal a significant shift in phase boundaries compared to the classical model, alongside the emergence of disordered regions without conventional magnetic order. This highlights the importance of quantum fluctuations when interpreting experimental observations in pyrochlore magnets.

MA 21.10 Wed 12:00 H18

Dynamical response of the Kitaev quantum spin liquid in the $KJ\Gamma$-model under external magnetic field — •Peng Rao[1], Roderich Moessner[2], and Johannes Knolle[1,3,4] — [1]Physics Department, Technical University of Munich, TUM School of Natural Sciences, 85748 Garching, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [4]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

We study the dynamical structure factor of the Kitaev quantum spin liquid (KQSL) generally, i.e. away from the solvable Kitaev limit, in the $KJ\Gamma$-model with external magnetic field. Using Majorana mean field theory, we compute spin susceptibility by including Majorana interactions in the random phase approximation (RPA). At zero field for the pure Kitaev model, RPA reproduces qualitatively spin susceptibility in the adiabatic approximation, which is close to the exact result. Small non -Kitaev couplings J and Γ induce sharp low-energy magnon modes as Majorana bound states. Larger couplings or finite field generally tend to weaken the KQSL and cause the sharp modes to condense, whence the system becomes magnetically ordered. However in specific paramter regimes, magnetic field may destroy the zero-field magnetic order and stabilize KQSL at intermediate field values, thus exemplifying the proposed 'field-induced KQSL'.

MA 21.11 Wed 12:15 H18

Short-range spin correlations in the 3D face-centred frustrated spin-$\frac{5}{2}$ system $MnSn(OH)_6$ — •Kaushick K. Parui[1], Anton A. Kulbakov[1], Ellen Häussler[2], Nikolai S. Pavlovskii[1], Roman Gumeniuk[3], Thomas Doert[2], Maxim Avdeev[4], Dmytro S. Inosov[1], and Darren C. Peets[1] — [1]IFMP, TU Dresden, Germany — [2]AC II, TU Dresden, Germany — [3]IEP, TU Bergakademie Freiberg, Germany — [4]ANSTO, Australia

Manganese tin hydroxide, $MnSn(OH)_6$, is an A-site-vacant double perovskite with magnetic Mn^{2+} ions on a face-centred sublattice, creating frustration that may lead to exotic magnetism. Combined x-ray and neutron diffraction data analysis reveals tetragonal $P4_2/n$ symmetry with precise H/D positions. Despite dominant antiferromagnetic interactions among Mn^{2+} moments, evidenced by a negative Curie-Weiss temperature, the lack of a sharp thermodynamic transition down to 350 mK implies the absence of long-range magnetic order. This suppression of the magnetic order hints towards a large frustration factor >10. Low-temperature neutron diffraction performed at 20 mK shows the absence of sharp magnetic Bragg peaks but reveals broad diffuse peaks, indicating 3D antiferromagnetic short-range interactions with a correlation length of roughly three unit cells.

MA 21.12 Wed 12:30 H18

Understanding the Hamiltonian of α-$RuCl_3$ through Nonlinear Spin-Wave Analysis — •Jonas Habel[1,2], Roderich Moessner[3] und Johannes Knolle[1,2,4] — [1]Technical University of Munich, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [4]Blackett Laboratory London, UK

The precise values of the magnetic exchange couplings in α-$RuCl_3$ are of significant interest to understand the proposed Kitaev spin-liquid phase. A common method for extracting them involves fully field-polarizing the magnetic moments, performing an inelastic neutron scattering (INS) experiment, and fitting a non-interacting (linear) spin-wave theory to the data. However, due to magnetic frustration, magnon many-body interactions are strong in α-$RuCl_3$ and cannot be neglected, even at high fields. We present a procedure for fitting an interacting (nonlinear) spin-wave theory to INS data, explicitly accounting for these many-body interactions. This reveals a significant renormalization of the exchange couplings compared to linear spin-wave estimates.

MA 22: Caloric Effects in Ferromagnetic Materials

Time: Wednesday 9:30–11:30 Location: H19

MA 22.1 Wed 9:30 H19

Utilizing frustration in Gd- and Yb-based oxides for milli-Kelvin adiabatic demagnetization refrigeration — •Tim Treu[1], Prachi Telang[1], Marvin Klinger[1], Alexander Tsirlin[2], Anton Jesche[1], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg — [2]Felix Bloch Institute for Solid-State Physics, University of Leipzig

Gadolinium- and Ytterbium-oxide based frustrated magnets have recently been characterised as excellent millikelvin adiabatic demagnetization refrigerants [1]. They offer several advantages over conventional paramagnetic hydrated salts, such as higher entropy density at similar minimum temperatures, chemical stability and UHV compatibility. We present a comprehensive study of the structural, magnetic and thermodynamic properties as well as the adiabatic demagnetisation refrigeration performance of several different Gd- and Yb-based oxides (including [1-2] and further unpublished results). For the temperature range between 0.03 and 2 K, a systematic comparison of the field-induced entropy density change and the refrigerant capacity is provided, demonstrating the advantages of frustrated magnets for low-temperature ADR.

Work supported by the German Research Foundation through the project 514162746 (GE 1640/11-1).

[1] T. Treu et al., J. Phys. Condens. Matter 37, 013001 (2025).
[2] P. Telang et al., arXiv:2411.04805

MA 22.2 Wed 9:45 H19

High-throughput design of all-d-metal Heusler alloys for transverse thermoelectric applications — •Fu Li, Hao Wang, Ruiwen Xie, and Hongbin Zhang — Technical University of Darmstadt, 64287 Darmstadt, Germany

Magnetic materials with prominent topological transport properties have been attracting significant attention due to the underlying intriguing physics and great potentials in various applications. Among these, Heusler alloys are particularly interesting because of their compositional flexibility which enables tunability of their physical properties via chemical doping. In this work, we perform high-throughput density functional theory calculations to evaluate the effects of chemical doping on the intrinsic anomalous Hall conductivity (AHC) and anomalous Nernst conductivity (ANC) in all-d-metal Heusler compounds, where chemical alloying with neighboring elements is considered using the virtual crystal approximation. The AHC and ANC are computed using the tight-binding Hamiltonian by automatically constructing the maximally localized Wannier functions. It is observed that rigid band model does not apply in all cases, because not only the Fermi energy has been shifted, but also the band structure has modified significantly. For (Pt0.7Ir0.3)2RhFe, detailed analysis reveals that the significant AHC and ANC are originated from the Weyl points close to the Fermi energy. These findings highlight the critical importance of chemical doping in the development of high-performance materials.

MA 22.3 Wed 10:00 H19

Electronic structure of all-d-metal Ni(-Co)-Mn-Ti vs. p-d Ni_2MnSn: DFT and XAS insights — •Olga Miroshkina[1], Johanna Lill[1], Benedikt Eggert[1], Benedikt Beckmann[2], David Koch[2], Franziska Scheibel[2], Katharina Ollefs[1], Wolfgang Donner[2], Oliver Gutfleisch[2], Heiko Wende[1], and Markus 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 caloric materials for energy efficient solid-state refrigeration [1]. We investigate the peculiar differences of the electronic structure between d-d Ni(-Co)-Mn-Ti and p-d Ni_2MnSn by combining density functional theory and x-ray absorption spectroscopy (XAS). To retrieve the distinctive characteristics of d-d orbital hybridization in K- and $L_{2,3}$-edges spectra, we correlate the features in the electronic densities of states (DOS) and XAS. The comparison of d-d Ni(-Co)-Mn-Ti with the conventional p-d Ni_2MnSn enables us to reveal the impact of the third d-element on magnetic and vibrational properties. The correlation of the calculated and measured XAS shows the presence of (partial) disorder not only in all-d-metal systems, but also in p-d Ni_2MnSn sample. This is consistent with our earlier findings of the traces of atomic disorder in the vibrational DOS [2]. Therefore, the interatomic hybridization in all-d-metal Heusler compounds can be utilized as an intrinsic control parameter for designing high-performance caloric materials.

[1] B. Beckmann *et al.*, *Acta Materialia* **246** 118695 (2023).
[2] O. Miroshkina *et al.*, *Phys. Rev. B* **106**, 214302 (2022).

MA 22.4 Wed 10:15 H19

Magnetocrystalline anisotropy of magnetocaloric Fe_2AlB_2 single crystals — •Nicolas Josten[1], Ralf Meckenstock[1], Anna Semisalova[1], Benedikt Beckmann[2], Konstantin Skokov[2], Oliver Gutfleisch[2], Hanna Pazniak[3], Thierry Ouisse[3], Michael Farle[1], and Ulf Wiedwald[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg Essen, Germany — [2]Functional Materials, Institute of Materials Science, Technical University of Darmstadt, Germany — [3]LMGP, Grenoble INP, CNRS, Université Grenoble Alpes, France

Fe_2AlB_2 is a low-cost, low weight and easily synthesized material composed of abundant elements for magnetocaloric applications near room temperature [1]. It is a ferromagnetic MAB phase with an orthorhombic crystal structure and a Curie-temperature T_C = 274 K [2]. The low crystal symmetry of Fe_2AlB_2 leads to a significant magnetocrystalline anisotropy up to around 1 $MJ\cdot m^{-3}$ at 10 K. We determined the temperature-dependent magnetocrystalline anisotropy constants of a bulk Fe_2AlB_2 single crystal using the Sucksmith-Thomson method and broadband ferromagnetic resonance measured along principal crystallographic directions. Both methods show perfect quantitative agreement.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) * Project-ID 405553726 * SFB/TRR 270.

[1] B. Beckmann et al. J. Appl. Phys. 133, 173903 (2023)
[2] T. N. Lamichhane et al. Phys. Rev. Mater. 2, 084408 (2018)

MA 22.5 Wed 10:30 H19

Effect of boron doping on the magnetocaloric properties in La(Fe, Si)$_{13}$ — •M. Strassheim[1,2], C. Salazar-Mejía[1], J. Wosnitza[1,2], and T. Gottschall[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]TU Dresden, Dresden, Germany

Traditional refrigeration methods rely on gases and toxic refrigerants, contributing to environmental degradation and energy inefficiencies. In contrast, magnetocaloric materials offer a promising alternative, with the ability to produce large, reversible thermal changes when exposed to magnetic fields. Among these, La(Fe,Si)$_{13}$-based compounds stand out due to their excellent magnetocaloric effect at near-room temperatures, relatively high transition temperatures, and comparatively low cost of the base elements, making them ideal candidates for practical applications. The influence of elements such as hydrogen and carbon on interstitial sites of the La(Fe,Si)$_{13}$ lattice is already well understood, but boron doping is not. We present a study of the latter in regard of magnetization and transition temperature with a perspective of both room-temperature and cryogenic applications.

MA 22.6 Wed 10:45 H19

Direct measurements of the adiabatic temperature change of a dysprosium single crystal — •E. Bykov[1], T. Gottschall[1], J. Wosnitza[1,2], C. Salazar Mejia[1], 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

Heavy rare-earth elements in the Gd-Tm series have unique magnetic properties due to their electronic structure. The exchange between $4f$ electrons occurs via RKKY interactions and, therefore, is extremely sensitive to the ionic radii of the elements, exhibits anisotropy, and shows pronounced magnetoelastic coupling. This leads to various magnetic phase diagrams with different helicoidal magnetic structures despite similar chemical and physical properties of the $4f$ elements. The high total angular momentum enables significant magnetocaloric effects, which is relevant for magnetic refrigeration applications. Gadolinium, for instance, exhibits a notable magnetocaloric effect at room temperature, serving as a comparative standard. Prior research at the Dresden High Magnetic Field Laboratory demonstrated record magnetocaloric effects in terbium. Holmium's broad plateau in $\Delta T_{\rm ad}$ at 5 T suggests potential in cryogenic applications, such as for hydrogen liquefaction. Continuing our study of the magnetocaloric effect of the $4f$ elements, we present our recent results for a dysprosium single crystal.

MA 22.7 Wed 11:00 H19

Estimation of the inverse giant barocaloric effect in Fe_2P — •Sven Wiesekopsieker[1,2], Tapas Samanta[1], Chris Taake[1], Judith Bünte[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

The Fe_2P system has so far been explored with respect to the magnetocaloric effect, linked to it's first-order magnetostructural transition between a ferromagnetic high volume phase at low T and a paramagnetic low volume phase at high T. Both phases show a hexagonal structure (P$\bar{6}$2m space group) [1]. This transition also gives rise to the barocaloric effect (BCE), which we studied by means of an indirect method, consisting of magnetization measurements under pressure and ambient pressure differential scanning calorimetry [2]. Application of pressure shifts the transition by $-45.8(1.0)$ K/GPa. It is accompanied by a transition entropy change of $|\Delta S_{\rm tr}| = 1.06(0.16)$ J/(kg K), similar to that reported by Hudl et al. Under application of 0.74 GPa a moderate adiabatic temperature change of -0.65 K is observed.

[1] A. Koumina et al., Ann. Chim. Sci. Mat. 23, 177 (1998)
[2] X. J. He et al., J. Mater. Sci. 52, 2915 (2017)
[3] M. Hudl et al., Phys. Rev. B 90, 144432 (2014)

MA 22.8 Wed 11:15 H19

Towards the hydrogenation of DyCo2 for cryogenic magnetocaloric liquefaction applications — •Allan Döring, Imants Dirba, Fernando Maccari, Konstantin Skokov, and Oliver Gutfleisch — TU Darmstadt, Darmstadt, Germany

Hydrogen can play an important role in the carbon-neutral society. Liquid H2 stands out for its higher volume-to-energy ratio. However, the current liquefaction method sums up to 34% of the costs to liquefy H. The magnetocaloric cooling could be one alternative to improve the efficiency of this process. Hence, research for materials with intense magnetocaloric effect (MCE) between 20 K and 77 K is needed. Those materials exhibit the peak of the MCE at transition temperatures, such as the Curie temperature (TC). Further, the MCE is stronger in heavy rare-earth (Re) based compounds, such as ReCo2. However, some of the ReCo2 materials exhibit giant MCE in temperatures above 77 K, and one way to shift down TC of such compounds is by introducing H as interstitial atoms. The TC of DyCo2 was shifted down by 120 K through the hydrogenation processK. Further, partially hydrogenated samples showed two distinct TCs. By X-ray diffraction analysis a crystalline state was confirmed with distorted lattices. The magnetic entropy changes were measured in non-hydrogenates, partially and fully hydrogenated samples, revealing a peak of entropy change at 25 K after hydrogenation. The reversibility of hydrogenation and its microstructre was also investigated. We acknowledge the HyLICAL project through grant 101101461.

MA 23: Focus Session: Magneto-Transport and Magneto-Optics of Higher Orders in Magnetization I

Magneto-transport and magneto-optic effects linear in the magnetization M (e.g. anomalous Hall effect (AHE), Faraday effect or magneto-optic Kerr effect (MOKE)) are important magnetic phenomena in spintronics and magneto-optics for the characterization of magnetic samples by vectorial magnetometry, microscopy, spectroscopy and pump probe experiments. However, already some time ago, it has been shown that the angular dependence of the anisotropic magnetoresistance and of magneto-optic effects contains higher-order-in-M terms. In the last decade, these effects beyond the linear dependence on M, e.g. quadratic effects proportional to M^2, have been mainly utilized to investigate antiferromagnetic materials.

Recently, the third-order MOKE proportional to M^3, so-called cubic MOKE, was reported to be sensitive to the structural domain twinning in thin-film samples of (111) orientation. By investigating AHE and MOKE of higher orders in M, the multipolar structure of the Berry curvature in magnetization space can be probed. These additional higher-order contributions in standard Hall or polar MOKE setup geometries are able to trace the in-plane magnetization while the linear effect keeps sensitive to the out-of-plane magnetic moment. This can be utilized, for example, to detect spin-orbit torques magneto-optically.

This Focus Session introduces the main magneto-transport and magneto-optic effects of higher orders in magnetization, draws connections between both research fields, distinguishes between already known and new higher-order effects and presents first applications beyond the study of antiferromagnets by quadratic effects.

Coordinators: Timo Kuschel, Bielefeld University, tkuschel@physik.uni-bielefeld.de;
Jaroslav Hamrle, Charles University, Prague, jaroslav.hamrle@matfyz.cuni.cz

Time: Wednesday 9:30–13:00 Location: H20

Invited Talk MA 23.1 Wed 9:30 H20

Magneto-transport effects in crystalline magnetic films — •Sebastian T. B. Goennenwein — Fachbereich Physik, Universität Konstanz, Konstanz, Germany

The magneto-transport response of magnetically ordered materials – such as the anisotropic magneto-resistance (AMR), or the anomalous Hall effect (AHE) – has been extensively studied in the last decades. While the magneto-transport response of amorphous or polycrystalline samples can often be described by comparatively simple expressions, the implications of crystal symmetry lead to a much richer and more complex response in single-crystalline specimens [1]. In particular, higher-order terms with a seemingly 'unconventional' dependence on the magnetization can be allowed by symmetry, and indeed also be detected in experiment [2].

In the presentation, I will first review the implications imposed onto the magneto-transport response by crystal symmetry, and then discuss typical experimental results, focusing on crystalline (Ga,Mn)As films as a prototypical and well-studied example [3,4]. If time permits, I will furthermore touch upon the impact of crystalline symmetry onto the magneto-thermopower response.

[1] R. R. Birss, *Symmetry and Magnetism* (North-Holland, Amsterdam, 1966)
[2] P. K. Muduli *et al.*, Phys. Rev. B **72**, 104430 (2005)
[3] W. Limmer *et al.*, Phys. Rev. B **74**, 205202 (2006)
[4] W. Limmer *et al.*, Phys. Rev. B **77**, 205210 (2008)

Invited Talk MA 23.2 Wed 10:00 H20

Cubic magneto-optic Kerr effect in thin films depending on structural domain twinning and crystal orientation — •Robin Silber[1], Maik Gaerner[2], Jaroslav Hamrle[3], and Timo Kuschel[2] — [1]VSB - Technical University of Ostrava, Czechia — [2]Bielefeld University, Germany — [3]Charles University, Czechia

Many of the second-order effects in magnetization in magneto-transport and magneto-optics are of practical importance in research and applications today. In the case of magneto-optic Kerr effect (MOKE), the second-order effect (quadratic MOKE) has been utilized to e.g. study antiferromagnetics [1] or to investigate spin-orbit torques in insulating structures [2], while the third-order effect (cubic MOKE, CMOKE) has only been discussed rarely so far [3, 4]. Here we provide a solid theoretical background for the phenomenological description of CMOKE for (111)- and (001)-oriented cubic crystal structures and compare the results with the experimental data collected on Ni(111) and Ni(001) thin film samples. CMOKE manifests as a three-fold angular dependence in Ni(111) thin films while for Ni(001) a four-fold angular dependence of CMOKE is predicted. The dependence on the incidence angle is changing from one to the other crystal orientation. Furthermore, the strength of the CMOKE is also sensitive to the degree of twinning of the Ni(111) thin film [4].

[1] V. Saidl et al., Nat. Photonics 11, 91 (2017).
[2] M. Montazeri et al., Nat. Commun. 6, 8958 (2015).
[3] A. V. Petukhov et al., J. Appl. Phys. 83, 6742 (1998).
[4] M. Gaerner et al., Phys. Rev. Applied 22, 024066 (2024).

MA 23.3 Wed 10:30 H20

Unconventional Magneto-Optical Effects — •Rudolf Schäfer and Ivan Soldatov — Leibniz Institute for Solid State and Materials Research (IFW), Dresden, Germany

Numerous magneto-optical reflection effects will be discussed that have hardly been considered in the past and that lead to intensity-based domain contrast in the absence of analyser and compensator in a wide-field magneto-optical microscope: (i) The transverse Kerr effect can be applied for in-plane magnetized material. (ii) In- and out-of-plane magnetized material can be imaged by circularly polarized light, leading to domain contrasts with different symmetry as the conventional Kerr contrast. (iii) Plane-polarized light at a specific angle can be employed for both in-plane and perpendicular media (Oppeneer effect). (iv) Perpendicular light incidence leads to a contrast on in-plane materials that is quadratic in the magnetization and to a domain boundary contrast. In case (iii), the contrast is generated by magnetic circular dichroism, while magnetic linear dichroism is responsible for the contrast in case (iv). The latter, being due to the diagonal elements in the quadratic dielectric magneto-optical tensor has a different symmetry as the conventional linear birefringence (Voigt) effect which is due to the off-diagonal elements. The domain*boundary contrast is caused by the magneto-optical gradient effect, which also exists as birefringence and dichroic effect. Reference: R. Schäfer, et al., Appl. Phys. Rev. 8, 031402 (2021)

MA 23.4 Wed 10:45 H20

Multipolar anisotropy in anomalous Hall effect from spin-group symmetry breaking — •Zheng Liu — University of Science and Technology of China, Hefei, China

Traditional view of the anomalous Hall effect (AHE) in ferromagnets is that it arises from the magnetization perpendicular to the measurement plane and that there is a linear dependence on the latter. However, this view is squarely challenged by a number of experiments recently, urging for a thorough theoretical investigation on the fundamental level. We find that for strong magnets, it is more appropriate and fruitful to regard the AHE as a spin-group symmetry breaking phenomenon where the critical parameter is the spin-orbit interaction strength, which involves a much smaller energy scale. Born out of our framework is a rich multi-polar relationship between the anomalous Hall conductivity and the magnetization direction, with each pole being expanded progressively in powers of the spin-orbit coupling strength. For the leading order contribution, i.e., the dipole, its isotropic part corresponds to the traditional view, and its anisotropic part can lead to the in-plane AHE where the magnetization lies within the measurement plane. Beyond the dipolar one, the octupolar structure offers the leading order source of nonlinearity and hence introduces unique anisotropy where the dipolar structure cannot. The dipolar and octupolar structure offers a unified explanation for the in-plane AHE recently observed in various ferromagnets. Our theory lays the ground for decoding the coupling between various transport and optical phenomena and the magnetic orders.

15 min. break

Invited Talk MA 23.5 Wed 11:15 H20

electrical and optical detection of the multipolar structure in the magnetization space — •Dazhi Hou — University of Science and Technology of China, Hefei, China

The anomalous Hall effect (AHE) in ferromagnetic materials has traditionally been understood to originate from a dipolar magnetization, with the effect typically showing sensitivity to out-of-plane magnetization. In contrast, we present compelling evidence that the AHE fundamentally arises from multipolar contributions to the magnetization. This discovery enables the observation of AHE under in-plane magnetization in cubic ferromagnets such as iron and nickel, challenging the conventional view. The magnitudes of these multipoles align with theoretical predictions from our recently proposed multipolar structure of Berry curvature in magnetization space. Notably, the octupole term can dominate the AHE in certain conditions, as observed in a van der Waals ferromagnet. Furthermore, we introduce a novel MOKE geometry that detects both the magnitude and direction of the perpendicular magnetization component, enabled by the multipolar structure of Berry curvature. This orthogonal MOKE geometry reveals unique angle-dependent behaviors, providing a direct probe of the magnetization multipoles at optical frequency. Our findings offer new insights into the quantum geometry of magnetization and open new avenues for probing magnetic orders across both electrical and optical domains, offering a unified framework for the study of multipolar magnetization in the context of Berry curvature.

MA 23.6 Wed 11:45 H20

Polarization variation method for investigation of magnetic and magneto-optical anisotropies — •Tomáš Ostatnický, Zeynab Sadeghi, Jozef Kimák, Peter Kubaščík, Eva Schmoranzerová, Lukáš Nádvorník, František Trojánek, and Petr Němec — Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic

We present a newly developed method for all-in-one measurement of both magnetic anisotropy and anisotropy of magneto-optical (MO) coupling in magnetic materials. It fully relies on the quadratic MO response (in magnetization) of a sample. The method works in both the reflection and transmission at near-normal incidence, it is not limited by presence of components with linear MO response in setup and it does not require sample rotation during the experiment; it therefore allows measurements with a sample placed inside a cryostat. Measurement scheme is based on a scanning of the probe beam polarization change upon rotation of external magnetic field for several linear polarization of the probe laser. Numerical analysis of the full set of data allows us to recover magnitude and anisotropy of the MO coupling coefficient and we further determine the magnetic anisotropy of the sample by a fitting procedure. We demonstrate the precision of the method by characterizing several GaMnAs ferromagnetic samples with different Mn contents. Reliability of the method is confirmed by a perfect fit of the MO coupling constants with the predictions based on the G-tensor formalism and by a mutual agreement of magnetic anisotropic constants, determined from data acquired at different wavelengths.

MA 23.7 Wed 12:00 H20

Magnetic polymorphism in 2D layered antiferromagnets — •Shiwei Wu — Department of Physics, Fudan University

Polymorphism, commonly denoting the variety of molecular or crystal structures, is a vital element in many natural science disciplines. In van der Waals layered antiferromagnets, a new type of magnetic polymorphism is allowed by having multiple layer-selective magnetic structures with the same total magnetization. However, resolving and manipulating such magnetic polymorphs remain a great challenge. In this talk, I will report the use of phase-resolved magnetic second-harmonic generation microscopy to elucidate such magnetic polymorphism in the 2D semiconducting layered antiferromagnet CrSBr, and demonstrate how the magnetic polymorphs can be deterministically switched in an unprecedented layer-selective manner. With the nonlinear magneto-optical technique unveiling the magnetic symmetry information through the amplitude and phase of light, we could unambiguously resolve the polymorphic spin-flip transitions in CrSBr bilayers and tetralayers. Remarkably, the deterministic routing of polymorphic transitions originates from the breaking of energy degeneracy via a magnetic layer-sharing effect: the spin-flip transitions in a tetralayer are governed by the laterally extended bilayer, which acts as a *control bit*. We envision such controllable magnetic polymorphism to be ubiquitous for van der Waals layered antiferromagnets, and could lead to conceptually new design and construction of spintronic and opto-spintronic devices for probabilistic computation and neuromorphic engineering.

MA 23.8 Wed 12:15 H20

Anisotropy of the contributions to the orbital magnetization — •Milan Vrána[1,2] and Jaroslav Hamrle[1,2] — [1]Charles University, Prague, Czech Republic — [2]Czech Technical University, Prague, Czech Republic

The general definition of orbital magnetization is the change in the grand canonical potential, Ω, with respect to the external magnetic field: $\mathbf{m}_{\mathrm{orb}} = -\partial\Omega/\partial\mathbf{B}$. The orbital magnetization consists of two distinct contributions [1]. The first term originates from the orbital motion of electrons and is given by $\mathbf{m}_{\mathrm{dip}} = -\frac{e}{2}\langle\psi|\mathbf{r}\times\mathbf{v}|\psi\rangle$. The second term, $\mathbf{m}_{\mathrm{kden}}$, has been reinterpreted as arising from changes in the density of **k**-points in phase space due to the concurrent presence of both the magnetic field and the Berry curvature, $\mathbf{\Omega}$ [2]. This violates Liouville's theorem, leading to an expansion or contraction of the phase space volume by a factor of $(1+\frac{e}{\hbar}\mathbf{B}\cdot\mathbf{\Omega})$. In the model material bcc Fe, we demonstrate that $\mathbf{m}_{\mathrm{kden}}$ is negligible in the [100] magnetization direction, whereas $\mathbf{m}_{\mathrm{dip}}$ is negligible in the [111] direction. It demonstrates different nature of the orbital magnetization for different magnetization directions. However, the magnitude of the total orbital magnetization, $\mathbf{m}_{\mathrm{orb}} = \mathbf{m}_{\mathrm{dip}} + \mathbf{m}_{\mathrm{kden}}$, remains nearly independent of the magnetization direction.

[1] F. Aryasetiawan, K. Karlsson, *Modern theory of orbital magnetic moment in solids*, J. Phys. Chem. Solids **128**, 87 (2019).

[2] Di. Xiao, *Berry Phase Modification to Electron Density of States and Its Applications*, dissertation, Texas University (2007).

Invited Talk MA 23.9 Wed 12:30 H20

Ultrafast Néel order dynamics detected by time-resolved magneto-optical Voigt effect — •Haibin Zhao — Fudan University, Shanghai, China

The time-resolved magneto-optical (MO) Voigt effect can be principally utilized to study the Néel order dynamics in antiferromagnetic (AFM) materials. In this talk, I will present the quench of AFM order by ultrafast laser pulses in both collinear and noncollinear AFM spin configurations in antiferromagnets with negligible net magnetization probed by the time-resolved MO Voigt effect. For CoO with collinear spin configuration, the quench time of Néel order slows down pronouncedly near the Néel temperature (TN). In contrast, for Mn3Sn with an inverse triangular spin structure, The AFM order quench time shows negligible change with increasing temperature approaching the TN. This atypical behavior can be explained by the influence of weakened Dzyaloshinskii-Moriya interaction rather than the smaller exchange splitting on the diminished AFM order near TN. The temperature-insensitive ultrafast spin manipulation can pave the way for high-speed spintronic devices either working at a wide range of temperature or demanding spin switching near TN. The modulated Voigt angle in Mn3Sn is significantly larger than the polarization rotation due to the crystal-structure related linear dichroism effect and the modulated MO Kerr angle arising from the ferroic ordering of cluster magnetic octupole.

MA 24: Focus Session: Nonlinear Spectroscopy of Collective Excitations in Quantum Magnets (joint session TT/MA)

In recent years, significant progress has been made in understanding strongly correlated quantum magnets, with a particular focus on fractionalized states of matter such as quantum spin liquids. These achievements in understanding have been made possible by remarkable developments in both materials science and experimental techniques. In particular, improvements in both traditional experimental tools (e.g., inelastic neutron scattering, Raman scattering, resonant X-ray scattering, etc.) and the introduction of innovative techniques such as 2D coherent THz spectroscopy and sophisticated noise experiments have advanced studies of quantum matter to qualitatively new levels of insight. This focus session will discuss these recent advancements in nonlinear spectroscopy techniques along with theoretical inroads in describing the nonlinear spectroscopic signatures of complex quantum magnets.

Organizers: Simon Trebst (Universität zu Köln), Johannes Knolle (TU München)

Time: Wednesday 9:30–12:45 Location: H36

Topical Talk MA 24.1 Wed 9:30 H36

Detecting Anyons Using Nonlinear Pump-Probe Spectroscopy — •Max McGinley[1,2], Michele Fava[2], and Sid Parameswaran[2] — [1]Cambridge University, UK — [2]Oxford University, UK

Topologically ordered two-dimensional systems can host excitations that possess statistics that interpolate between bosonic and fermionic—so called anyons. In this talk, I will explain how the presence of such anyonic excitations can be inferred from nonlinear spectroscopic quantities. In particular, we consider pump-probe spectroscopy, where a sample is irradiated by two light pulses with an adjustable time delay between them. The relevant response coefficient exhibits a universal form that originates from the statistical phase acquired when anyons created by the first pulse braid around those created by the second. This behaviour is shown to be qualitatively unchanged by non-universal physics including non-statistical interactions and small finite temperatures. In magnetic systems, the signal of interest can be measured using currently available terahertz-domain probes, highlighting the potential usefulness of nonlinear spectroscopic techniques in the search for quantum spin liquids. I will discuss future prospects for inferring properties of collective excitations using analogous techniques.

Topical Talk MA 24.2 Wed 10:00 H36

Two-Dimensional Nonlinear Dynamic Response of Frustrated Magnets — •Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, D-38106 Braunschweig, Germany

Two-dimensional nonlinear (2DNL) coherent optical spectroscopy is of great interest in order to deconvolute excitation continua in correlated magnets, potentially allowing to analyze individual quasiparticles, including those of fractionalized magnets. We discuss the relevant response functions for the coupling of spin systems to electric fields and analyze the 2DNL dynamical susceptibilities for two scenarios of frustrated magnetism, namely for a quantum spin-liquid (QSL) as well as for a case of incommensurate spiral long-range order (ICO). For the former, we consider the Kitaev magnet, which hosts a quantum spin-liquid, featuring fractionalization in terms of mobile Majorana fermions and static flux-visons. We show that the 2DNL response does not only probe characteristic features of both fractional excitations, but also allows to extract single quasiparticle lifetimes from its multi-particle continua. These properties will be discussed over a wide range of temperatures. For the case of 2DNL response from a magnet with ICO, we chose the J_1-J_3 spin-model on the square lattice. Here, some features of the 2DNL spectra are found to be remarkably similar to those of the QSL case. Going beyond a bare quasiparticle approach, we will also comment on the impact of final-state interactions.
Work done in collaboration with Olesia Krupnitska and profiting from interactions with Roser Valentí, Natalia Perkins, Marius Möller, Anna Keselman, and David Kaib.

Topical Talk MA 24.3 Wed 10:30 H36

Imaging Magnetization Dynamics and Collective Spin Excitations in Compensated Magnets on Ultrafast Timescales — •Benjamin Stadtmüller — Experimentalphysik II, Institute of Physics, Augsburg University, 86159 Augsburg, Germany

Fundamental to the advancement of spintronics and quantum technologies is the ability to encode, manipulate and store information in the spin angular momentum of electrons on ever faster timescales. In this contribution, we therefore discuss the ultrafast magnetic response of compensated magnets, which are interesting candidates for applications due to their robustness against external fields and their fast manipulation speed. We start with the ultrafast magnetization dynamics of conventional antiferromagnets (AFMs), for which the possibility of optical excitation of collective magnon modes on ps timescales has already been demonstrated. For the case of NiO, we show that these timescales can be further reduced by exploiting the strong non-equilibrium excitation with fs laser pulses. These conditions lead to a significant loss of magnetic order and to the excitation of collective magnon modes. We then turn to the ultrafast optical response of the recently discovered class of altermagnets with their d-wave-like spin split band structure. By combining theoretical calculations with ultrafast magneto-optical experiments, we demonstrate the generation of a macroscopic spin polarization in the otherwise fully compensated altermagnet RuO_2, which can additionally be controlled by the excitation geometry [1]. [1] M. Weber and S. Wust et al. arXiv: 2408.05187

15 min. break

Topical Talk MA 24.4 Wed 11:15 H36

Revealing Dynamics of Hidden Sectors with Nonlinear Spectroscopy — •Yoshito Watanabe[1], Simon Trebst[1], and Ciarán Hickey[2,3] — [1]Institute for Theoretical Physics, University of Cologne, Cologne, Germany — [2]School of Physics, University College Dublin, Belfield, Dublin 4, Ireland — [3]Centre for Quantum Engineering, Science, and Technology, University College Dublin, Dublin 4, Ireland

Nonlinear spectroscopy, especially in its two-dimensional coherent spectroscopy (2DCS) form, is an emerging and promising tool for studying the dynamics of quantum materials. Unlike traditional linear probes, 2DCS employs a multi-pulse approach that reveals intricate dynamics, including the ability to resolve fractional excitation continua as sharp spinon-echo signals and to study interactions between excitations, phenomena often obscured in traditional measurements.

In this work, we focus on the potential of 2DCS to detect and characterize quadrupolar excitations in quantum magnets. Using exact diagonalization and establishing an effective Hamiltonian that reflects the dynamics of hidden sectors and higher-order excitations, we identify distinct spectroscopic features, including new signatures associated with quadrupolar excitations. These results provide a guide for the experimental detection and characterization of hidden dynamics in quantum materials.

Topical Talk MA 24.5 Wed 11:45 H36

Theory of Nonlinear Spectroscopy of Quantum Magnets — Anubhav Srivastava[1,2], •Stefan Birnkammer[1], GiBaik Sim[3], Michael Knap[1], and Johannes Knolle[1,4] — [1]Technical University of Munich, Garching, Germany — [2]Indian Institute of Science, Bengaluru, India — [3]Hanyang University, Seoul, Korea — [4]Imperial College London, London, United Kingdom

Two-dimensional coherent spectroscopy (2DCS) is an established method for probing molecules and has been proposed in the THz regime as a new tool for probing exotic excitations of quantum magnets but the precise nature of coupling between pump field and spin degrees of freedom has remained unclear. Here, we develop a general response theory of 2DCS and show how magneto-electric as well as polarization couplings contribute to 2DCS in addition to the standardly assumed magnetization. We propose experimental protocols to distill individual coupling contributions, for example from exchange-striction or spin current mechanism. We provide example calculations for the paradigmatic twisted Kitaev chain material $CoNb_2O_6$ and highlight the crucial role of contributions from cross-coupling between polarization and magnetic nonlinear susceptibilities. Our work paves the way for systematic studies of light-matter couplings in quantum magnets and for establishing 2DCS as a versatile tool for probing fractional excitations of exotic magnetic quantum phases.

MA 24.6 Wed 12:15 H36

Quantitative Prediction of the Dynamics of In-Gap States in Correlated Materials as Seen in Pump-Probe PES, XAS and RIXS Experiments: A NiO Case Study — •Sina Shokri and Maurits W. Haverkort — Universität Heidelberg, Institut für Theoretische Physik, Philosophenweg 19, Heidelberg 69120 Germany

Attosecond pump-probe experiments allow one to study and steer quantum materials on their fundamental time-scales. For atoms and small molecules one can theoretically predict the electronic and vibrational dynamics induced by ultra-fast light pulses [1,2]. In solids a theoretical understanding is much harder. The coupling to many continuous degrees of freedom can result into rapid loss of coherence. Quantitative predictions how coherently driven excitations decohere is highly non-trivial. Correlated Mott- Hubbard or charge transfer insulators can show a variety of long lived excitonic excitations within the optical gap. With attosecond pump-probe spectroscopy it is possible to investigate the propagation and decay of such excitations, as recently shown by two-photon photo-emission spectroscopy of NiO. These experiments show photo-induced, long-lived in-gap states with coherent oscillations [3]. In this talk we will show, using non-linear response theory, how to quantitatively predict the dynamics of in-gap states in correlated materials after an optical excitation. We will furthermore show how this dynamics can be probed with different pump-probe experiments including photo-emission spectroscopy, x-ray absorption spectroscopy and resonant inelastic x-ray scattering.

[1] PRL 128, 153001 (2022).
[2] PRA 108, 032816 (2023).
[3] Nat. Commun. 11, 4095 (2020).

MA 24.7 Wed 12:30 H36

Higher-Order Susceptibilities in Extended Kitaev Models Computed Via Krylov-Space Based Methods — •David Kaib, Marius Möller, and Roser Valenti — Institut für theoretische Physik, Goethe-Universität Frankfurt

Recently, it was proposed that techniques measuring higher-order dynamical response, such as two-dimensional coherent spectroscopy (2DCS), could provide more distinguishable signatures in analyzing the excitations of different systems. This is particularly true when linear response reveals only a featureless continuum, which could arise from various different types of excitations, or, for example, static disorder. The numerical evaluation of nonlinear response functions can, however, be computationally very demanding. Here, we propose an efficient Lanczos-based method that computes higher-order susceptibilities directly in the frequency domain. As an application case, we consider extended Kitaev models, that are relevant to α-$RuCl_3$ and related materials. We compare the nonlinear response from our method to the one obtained within linear spin-wave theory, showcasing that nonlinear response measurements can distinguish whether an observed excitation continuum is of conventional two-magnon type or has a different origin.

MA 25: Focus Session: Physics of the van der Waals Magnetic Semiconductor CrSBr I (joint session HL/MA)

The session is the first part of the focus session on the physics of the van der Waals magnetic semiconductor CrSBr, with a main session on Friday morning. The focus session is jointly organized by HL and MA.

Time: Wednesday 15:00–15:30 Location: H15

MA 25.1 Wed 15:00 H15

Doping-control of excitons and magnetism in few-layer CrSBr — •Farsane Tabataba-Vakili[1,2,3], Anna Rupp[2], Huy Nguyen[2], Anvar Baimuratov[2], and Alexander Högele[2,3] — [1]Institute of Condensed Matter Physics, Technische Universität Braunschweig, Braunschweig, Germany — [2]Fakultät für Physik, Munich Quantum Center, and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München, München, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

In two-dimensional (2D) magnets, phenomena distinct from bulk magnetism have been revealed, such as sensitivity to charge doping and electric field in few-layer CrI3. Within the class of 2D magnets, air-stable CrSBr stands out as an antiferromagnetic semiconductor with a high Néel temperature, excitons coupled to the magnetic order, and exciton-magnon coupling. In this talk, I will present our work on doping-control of excitons and magnetism in few-layer CrSBr [1]. We demonstrate that both exciton and magnetic transitions are sensitive to field-effect charging, exhibiting bound exciton-charge complexes and doping-induced metamagnetic transitions. We further visualize magnetic domain formation induced by magnetic field or charge-doping at the metamagnetic transition all-optically by raster-scan reflectance imaging. Our work identifies few-layer CrSBr as a rich platform for exploring collaborative effects of charge, optical excitations, and magnetism.

[1] F. Tabataba-Vakili et al., Nat. Commun. 15, 4735 (2024).

MA 25.2 Wed 15:15 H15

Proximity-Induced Exchange Interaction and Prolonged Valley Lifetime in $MoSe_2$/CrSBr Van-Der-Waals Heterostructure with Orthogonal Spin Textures — •Andreas Beer[1], Klaus Zollner[1], Caique Serati de Brito[1,2], Paulo E. Feria Junior[1], Philipp Parzefall[1], Talieh S. Ghiasi[3], Josep Ingla Aynés[3], Samuel Mañas-Valero[4], Carla Boix-Constant[4], Kenji Watanabe[5], Takashi Taniguchi[5], Jaroslav Fabian[1], Herre S. J. van der Zant[3], Yara Galvão Gobato[2], and Christian Schüller[1] — [1]UR, Regensburg, Germany — [2]UFSCar, São Carlos, Brazil — [3]TU, Delft, Netherlands — [4]ICMol, València, Spain — [5]NIMSC, Tsukuba, Japan

We report a comprehensive optical study of a ML-$MoSe_2$ on the layered A-type antiferromagnetic semiconductor CrSBr. The band alignment of the material combination is under debate. Here, we adopt the type-III band alignment picture. By performing co-circular polarized PL and reflection contrast (RC) experiments, we observe that the atomic proximity of the materials leads to an unexpected breaking of time-reversal symmetry, despite the originally perpendicular spin texture in both materials, which are further supported by first-principles calculations. Moreover, time-resolved PL and time-resolved RC measurements identify a very long-lived dynamic charge-transfer process in the heterostructure, consistent with a type-III band alignment. Our findings suggest band bending, and efficient Förster resonance energy transfer within the heterostructure. Finally time resolved Kerr ellipticity measurements reveal a two magnitudes prolonged valley lifetime.

MA 26: Ultrafast Magnetization Effects I

Time: Wednesday 15:00–18:45 Location: H16

MA 26.1 Wed 15:00 H16

Terahertz field assisted magneto-optical effects in nonmagnetic substrates — •Sergey Kovalev[1], Igor Ilyakov[2], Anneke Reinold[1], Patrick Pilch[1], Ahmed Ghalgaoui[1], Ruslan Salikhov[2], Jürgen Lindner[2], Cong Li[3], Jianbing Zhang[3], Pu Yu[3], and Zhe wang[1] — [1]Fakultät Physik, Technische Universität Dortmund, Dortmund, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Tsinghua University, China

Coherent control of matter on ultrafast timescales is attracting much attention due to numerous applications in advanced technologies. Strong terahertz (THz) fields are highly demanded in many of these studies, which focus on the control of carrier flow, spin dynamics, orbital polarisation and various aspects of nonlinear electron dynamics. For these studies it is very important to understand and disentangle different THz field induced processes occurring in the investigated systems and their substrates. In this contribution, we present two effects that occur in fused silica [1] and in LaAlO3 driven by strong THz field, resulting in rotation of laser pulse polarisation. These observations are due to the magneto-optical effect in amorphous systems or the Kerr electro-optical effect in anisotropic systems. Our results show that in general these effects should be carefully considered in the studies of ultrafast THz magnetisation dynamics by ultrafast pump-probe approaches. [1] S. Kovalev et al., Optics Letters 49, 4749 (2024)

MA 26.2 Wed 15:15 H16

Photoinduced spectral manipulation of coherent magnonics in ultrathin iron garnets — •Volker Wiechert[1], Moritz Cimander[1], Hanchen Wang[2], William Legrand[3], Pietro Gambardella[2], and Davide Bossini[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]Department of Materials, ETH Zürich, Hönggerbergring 64, CH-8093 Zürich, Switzerland — [3]Unité Mixte de Physique, CNRS, Université Paris-Saclay, Palaiseau 91767, France

Iron garnets, particularly Bi:YIG thin films, are promising materials for magnonics and magnetotransport due to their low damping and tunable magnetic properties through doping or external magnetic fields [1]. Recent advances demonstrate the ability of ultrashort laser pulses to excite, control, and even switch magnetization with minimal heating [2-4]. In this study, we investigate Bi:YIG single crystals in quasi-2D ultrathin form (~20 nm), using a femtosecond, balanced-detection scheme to capture simultaneous optical and magneto-optical responses. Our findings reveal two pathways for modifying magnetic resonance eigenfrequency: an impulsive femtosecond modification of magneto-crystalline anisotropy and a nanosecond lattice-mediated heating effect. This dual effect is quantitatively identified in time-resolved experiments, with potential applications in other quasi-2D ultrathin magnetic systems exhibiting temperature-dependent phase transitions.

[1] C. Holzmann et al., ACS Appl. Nano Mater. 5(1), 2022 [2] F. Hansteen et al., PRB 73, 2006 [3] L. Soumah et al., PRL 127, 2021 [4] A. Stupakiewicz et al., Nature 542, 2007

MA 26.3 Wed 15:30 H16

Ultrafast Entropy Production in Non-Equilibrium Magnets — •Finja Tietjen and R. Matthias Geilhufe — Chalmers University of Technology, Gothenburg, Sweden

We present an ultrafast thermodynamics framework to model heat generation and entropy production in laser-driven ferromagnetic systems. By establishing a connection between the magnetic field strength of the laser pulse and magnetization dynamics we model time-dependent entropy production rates and deduce the associated heat dissipation in epitaxial and polycrystalline FeNi and CoFeB thin films. Our theoretical predictions are validated by comparison to experimental magnetization dynamics data, shedding light on thermodynamic processes on picosecond timescales.

Crucially, we incorporate recently observed inertial spin dynamics, to describe their impact on heat generation in pump-probe experiments. As such, this formalism provides novel insights into controlling heat production in magnetic systems, and contributes to advancing the understanding of non-equilibrium thermodynamics in magnetic systems, with implications for future experimental protocols in spintronics and nanotechnology.

[1] F. Tietjen, & R. M. Geilhufe (2024). Ultrafast Entropy Production in Non-Equilibrium Magnets. arXiv preprint arXiv:2410.23205.

MA 26.4 Wed 15:45 H16

Spin-lattice modeling of elastic waves generated by ultrafast demagnetization in fcc Ni — •Ievgeniia Korniienko[1], Pablo Nieves[2], Alberto Fraile[3], Roberto Iglesias[2], and Dominik Legut[1] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czech Republic — [2]University of Oviedo, Oviedo, Spain — [3]Catalan Institute of Nanoscience and Nanotechnology (ICN2), Barcelona, Spain

Picosecond ultrasonics is a fast growing and advanced research field with broad application to the imaging and characterization of nanostructured materials as well as at a fundamental level. Experiments that provide direct, layer-specific, and quantitative information on the picosecond strain response [1], however, face comparably limited theoretical descriptions and modeling. In our work we propose a 3D model on the base of atomistic spin-lattice simulations [2] for laser-induced elastic response. As an example for testing our modeling approach we use ferromagnetic fcc Ni. Such choice allows us not only to calculate the lattice elastic response including ultrafast thermal expansion, but also to characterize the magnetic contribution to stress in this material [3]. The theoretical approach presented in our work [3] can be useful for further interpretations of experiments in the picosecond ultrasonics, as well as for providing other required parameters (like ultrafast thermal expansion coefficient) in micromagnetic models, e.g. within a multiscale approach. References: [1] M. Mattern, et al.: Photoacoustics 31, 100503 (2023); [2] P. Nieves, et al.: Phys. Rev. B 103, 094437 (2021); [3] I. Korniienko, et al.: Phys. Rev. Research 6, 023311 (2024).

MA 26.5 Wed 16:00 H16

Ultrafast orbital Hall effect in metallic nanoribbons — •Oliver Busch, Franziska Ziolkowski, Börge Göbel, Ingrid Mertig, and Jürgen Henk — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

The orbital Hall effect can generate currents of angular momentum more efficiently than the spin Hall effect in most metals. However, so far, it has only been understood as a steady-state phenomenon [1]. In this theoretical study, the orbital Hall effect is extended into the time domain [2]. We investigate the orbital angular momenta and their currents induced by a femtosecond laser pulse in a Cu nanoribbon.

Our numerical simulations provide detailed insights into the laser-driven electron dynamics on ultrashort timescales with atomic resolution. As we show, the ultrafast orbital Hall effect described here is consistent with the familiar pictorial representation of the static orbital Hall effect, but we also find pronounced differences between physical quantities that carry orbital angular momentum and those that carry charge. For example, there are deviations in the time series of the respective currents. This work lays the foundations for investigating ultrafast Hall effects in confined metallic systems.

[1] D. Go *et al.* Europhysics Letters **135**, 37001 (2021)

[2] O. Busch *et al.*, Physical Review Research **6**, 013208 (2024)

MA 26.6 Wed 16:15 H16

Ultrafast magnetization dynamics of magnetic garnet thin films — •Paul Herrgen[1], Christian Holzmann[2], Manfred Albrecht[2], Benjamin Stadtmüller[2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany

The rare-earth iron garnets (REIG) are a class of magnetic oxide materials, known for their excellent magneto-optical properties, high magnetic permeability, and applications in photonics and spintronics. [1]

In our work we investigate the ultrafast magnetization dynamics of a gadolinium iron garnet (GdIG) thin film after an excitation with an ultrashort laser pulse. Our static characterization of the magnetic properties revealed hysteresis loops with opposite sign of the saturation magnetization for equal field directions depending on the probe photon energy. This points to a photon energy dependent magnetic response of both sublattices and allows us to disentangle their ultrafast response after optical excitation. We observe an ultrafast demagnetization of both sublattices within the first few hundred fs, after excitation with photon energies larger than the material's band gap. We find a different quenching for the signals of both sublattices despite the otherwise very similar demagnetization time. On longer timescales, we find another different behavior for the sublattices, with the iron sublattice starting to remagnetize much earlier than the gadolinium one.

[1]: C. Holzmann and M. Albrecht: Encyclopedia of Materials: Electronics 1, 777 (2023)

MA 26.7 Wed 16:30 H16

Accelerated ultrafast demagnetization of an interlayer-exchange-coupled Co/Mn/Co trilayer — •Jendrik Gördes[1], Ivar Kumberg[1], Chowdhury S. Awsaf[1], Marcel Walter[1], Tauqir Shinwari[1], Sangeeta Thakur[1], Sangeeta Sharma[2], Christian Schüssler-Langeheine[3], Niko Pontius[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Berlin — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin

We studied the influence of the spin structure of an antiferromagnetic (AFM) layer at the interface to a ferromagnetic (FM) layer on the FM magnetization dynamics in epitaxial Co/Mn/Co/Cu(001) trilayers. The two FM layers are coupled indirectly by the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction and directly by exchange through the AFM spin structure [1]. Deposition of Mn in a wedge allowed for access to different coupling regimes on the same sample. Magnetization dynamics were probed after excitation with 800 nm fs laser pulses by X-ray magnetic circular dichroism in reflectivity. A difference in demagnetization time between the two regimes for parallel and antiparallel alignment of FM is observed. We explain this by differences in the AFM spin structure leading to presence or absence of optically induced intersite spin transfer [2] between Mn and Co. [1] B. Zhang *et al.*, J. Appl. Phys. 115, 233915 (2014). [2] J. K. Dewhurst *et al.*, Nano Letters 18, 1842 (2018)

15 min. break

MA 26.8 Wed 17:00 H16

Development of planar micro optics for ultrafast in-situ measurements in the TEM — •Max Herzog[1], Johannes Schultz[1], and Axel Lubk[1,2] — [1]IFF, IFW Dresden, Helmholtzstraße 20, 01069 Dresden — [2]IFMP, TU Dresden, Haeckelstraße 3, 01069 Dresden

The miniaturization of magnetic electron optics has been a goal for at least the past decade, because it will not only allow for smaller and easier to build electron optics, but will also result in other favorable scaling effects. Namely, the small scale allows for magnetic flux densities in the hundreds of millitesla with a significantly reduced power consumption and lower overall complexity regarding vacuum, cooling and power supply. More important for this work, however, is the small inductance that follows from the small size, which in turn allows the optics to be switched with radio frequencies (RF). The aim of this work is to lithographically produce planar micro optics (e.g. deflectors, focusing quadrupoles, vector magnets, etc.), that are capable of utilizing this RF switching to image ns-scale processes (e.g. the movement of magnetic domain walls) stroboscopically in a transmission electron microscope. The optics were characterized using differential phase contrast (DPC) to determine the spatial distribution of the magnetic field and by measuring the optical power (e.g. deflection, focusing behaviour) at varying switching frequencies. Using an acceleration voltage of 80 kV, the optics show a promising performance with a deflection power of up to 330 μrad at an excitation frequency of 7.5 MHz and still 120 μrad at 2 GHz with a very homogeneous magnetic field as determined by DPC.

MA 26.9 Wed 17:15 H16

Ultrafast energy-resolved spin dynamics in nickel — Christopher Seibel, Tobias Held, Markus Uehlein, •Sebastian T. Weber, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau

Magneto-optical methods were used when ultrafast magnetization dynamics were discovered and are still used intensively. Recent experiments show a strongly energy-dependent magneto-optic response and indicate spin transfer processes on the timescale of the pulse duration in a pure metallic ferromagnet [1].

We investigate the non-equilibrium spin dynamics on these early timescales by full spin-resolved Boltzmann collision integrals [2]. We trace the temporal evolution of the individual distribution functions of up and down electrons, where spin-flips due to electron-electron and electron-phonon collisions are taken into account.

From the dynamics of the distributions, we extract the spin-resolved densities of both, electrons and holes, at various energies. The energy-resolved spin polarization can vary significantly depending on the considered energy range. It can deviate from the overall magnetization dynamics, both in terms of the qualitative behavior and the timescales involved. Additionally, we present results on the non-equilibrium magneto-optic response calculated from the distribution functions.

[1] H. Probst et al., *Phys. Rev. Res.* **6**, 013107 (2024)
[2] B. Müller et al., *Phys. Rev. Lett.* **111**, 167204 (2013)

MA 26.10 Wed 17:30 H16

Differentiating mechanisms that drive ultrafast magnetization precession — •Fried-Conrad Weber[1,2], Maximilian Mattern[3], Jasmin Jarecki[3], Marwan Deb[1], Dieter Engel[3], Daniel Schick[3], Alexander von Reppert[1] und Matias Bargheer[1,2] — [1]Universität Potsdam — [2]Helmholtz-Zentrum für Materialien und Energie, Berlin — [3]Max-Born-Institut, Berlin

We use the time-resolved polar magneto-optical Kerr effect to measure the laser-induced magnetization precession of a 20 nm and 200 nm thin nickel film for different external magnetic field angles. We identify the role of quasi-static strain, strain pulses, and demagnetization for driving the precession in these samples. The magnetization response is modeled using the udkm1Dsim toolbox, which calculates the temperature, strain, and subsequent magnetization response with a modified Landau-Lifshitz-Gilbert equation that incorporates demagnetization. Contributions from the demagnetization-induced change in anisotropy, quasi-static strain, and propagating strain pulses are included in the time-dependent effective field. In the case of nickel, the quasi-static strain drives the effective field in the opposite direction to the demagnetization-induced change in anisotropy. For the samples and fluences measured, we identify the laser-induced strain and the subsequent change in the magnetoelastic field as the dominant mechanism controlling the precession. In a subsequent double-pulse excitation experiment, we balance the effect of the demagnetizationinduced change in anisotropy and the magnetoelastic contribution in a non-conventional coherent control scheme.

MA 26.11 Wed 17:45 H16

Temperature and Magnetic Field Dependence of Ultrafast Magnetization Dynamics — •Leon Seidel[1], Clemens von Korff Schmising[2], Tino Noll[2], Wolfgang-Dietrich Engel[2], Simon Gaebel[2], Daniel Metternich[2], and Stefan Eisebitt[1,2] — [1]Technische Universität Berlin — [2]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie

In this work, we present a wide-field optical microscope designed to study the temperature and magnetic field dependence of ultrafast magnetization dynamics with femtosecond temporal and micrometer spatial resolution. The compact device integrates xyz, yaw and tilt adjustments as well as a motorized sample manipulation. The sample temperature is controlled by a continuous flow cryostat in a temperature range between 20 K / 80 K and 500 K using either LN2 or LHe. An inbuilt electromagnet provides an external magnetic field of up to one Tesla.

We show first results of ultrafast all-optical magnetization switching (AOS) in ferrimagnetic rare earth-transition metal alloys. We characterize two CoTbGd films with different stochiometries and systematically examine the role of the magnetization and angular momentum compensation for AOS.

MA 26.12 Wed 18:00 H16

Heterogenity of the laser-induced magneto-structural phase transition in FeRh revealed by ultrafast x-ray diffraction — •Maximilian Mattern[1], Jan-Etinne Pudell[2], Vojtech Uhlir[3], Jon Ander Arregi[3], Angel Rodriguez-Fernandez[2], Roman Shayduk[2], Wonhyuk Jo[2], Anders Madsen[2], and Daniel Schick[1] — [1]Max-Born-Institut, Germany — [2]European XFEL, Germany — [3]CEITEC BUT, Czech Republic

Laser-induced heterogeneities play an important role for ultrafast dynamics especially of first-order phase transitions due to the phase coexistence during nucleation. However, their probing on picosecond time and nanometer length scales is challenging.

We use time-resolved x-ray diffraction to reveal the transient nanoscale heterogeneity of the laser-induced first-order antiferromagnetic (AFM) to ferromagnetic (FM) phase transition in FeRh that is accompanied by a lattice expansion. Utilizing the good reciprocal space and femtosecond time-resolution of the MID instrument at the

European X-ray Free-electron laser, we individually track the picosecond shifts of the structural AFM and FM Bragg peak. The integral of the latter quantifies the transient fraction of the FeRh layer that is in the FM phase, and the signatures of the propagating picosecond strain pulses in the shift of both Bragg peaks reveal its spatial distribution. Our results can distinguish between different nucleation scenarios and reveal that the FM phase nucleates as laterally separated columns through the photoexcited near-surface region, finally forming a closed FM layer at the surface of the inhomogeneously excited FeRh film.

MA 26.13 Wed 18:15 H16

Ultrafast electron dynamics in altermagnetic materials — Marius Weber[1,2], •Kai Leckron[1], Luca Haag[1], Libor Šmejkal[2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics, University of Kaiserslautern-Landau, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, Germany

One of the intriguing properties of altermagnetic materials is that a linearly polarized optical pulse can induce a spin polarization of the electrons depending on the direction of the linear polarization [1]. This contribution investigates the impact of the polarization direction and fluence of the optical excitation on the ultrafast magnetization dynamics in the prototypical altermagnetic band structure of KRu4O8. We explicitly consider electron-electron scattering and electron-phonon scattering contributions to the light-driven carrier dynamics. The optical excitation is computed using ab initio dipole transition rates in the whole Brillouin zone. Our momentum-dependent calculation of the subsequent scattering dynamics fully includes the anisotropies of the altermagnet, which leads to unique k-resolved electron dynamics at ultrashort times and a long-lived spin polarization [2]. We present a numerical study of the influence of the excitation conditions on the lifetime of this spin polarization.

[1] M. Weber et al., arXiv:2408.05187 (2024) [2] M. Weber et al., arXiv:2411.08160 (2024)

MA 26.14 Wed 18:30 H16

The dynamics of a memory-enhanced LLG equation — •Felix Hartmann[1] and Janet Anders[1,2] — [1]University of Potsdam, Institute of Physics and Astronomy, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

Recently, Anders et al. [1] have proposed a stochastic Landau-Lifshitz-Gilbert (LLG) equation which takes into account memory effects and colored thermal fluctuations, with either a classical, semi-classical or quantum thermostat. In this talk we will present some recent results that characterize the spin dynamics in different parameter regimes. We show how the proposed stochastic LLG equation has a well-described white-noise and Markovian limit of the spin dynamics. Further, going beyond the white-noise and Markovian limit, we present numerical results that show strong ultrafast and inertial effects in the spin dynamics, such as a faster relaxation and the appearance of nutation oscillations.

[1] J. Anders et al., New J. Phys. 24 033020 (2022)

MA 27: Focus Session: Magneto-Transport and Magneto-Optics of Higher Orders in Magnetization II

Magneto-transport and magneto-optic effects linear in the magnetization M (e.g. anomalous Hall effect (AHE), Faraday effect or magneto-optic Kerr effect (MOKE)) are important magnetic phenomena in spintronics and magneto-optics for the characterization of magnetic samples by vectorial magnetometry, microscopy, spectroscopy and pump probe experiments. However, already some time ago, it has been shown that the angular dependence of the anisotropic magnetoresistance and of magneto-optic effects contains higher-order-in-M terms. In the last decade, these effects beyond the linear dependence on M, e.g. quadratic effects proportional to M^2, have been mainly utilized to investigate antiferromagnetic materials.

Recently, the third-order MOKE proportional to M^3, so-called cubic MOKE, was reported to be sensitive to the structural domain twinning in thin-film samples of (111) orientation. By investigating AHE and MOKE of higher orders in M, the multipolar structure of the Berry curvature in magnetization space can be probed. These additional higher-order contributions in standard Hall or polar MOKE setup geometries are able to trace the in-plane magnetization while the linear effect keeps sensitive to the out-of-plane magnetic moment. This can be utilized, for example, to detect spin-orbit torques magneto-optically.

This Focus Session introduces the main magneto-transport and magneto-optic effects of higher orders in magnetization, draws connections between both research fields, distinguishes between already known and new higher-order effects and presents first applications beyond the study of antiferromagnets by quadratic effects.

Coordinators: Timo Kuschel, Bielefeld University, tkuschel@physik.uni-bielefeld.de;
Jaroslav Hamrle, Charles University, Prague, jaroslav.hamrle@matfyz.cuni.cz

Time: Wednesday 15:00–15:45 Location: H18

MA 27.1 Wed 15:00 H18

Quantifying magnetization multipole of Berry curvature in ferromagnets — •Wenzhi Peng, Zheng Liu, Bin Xiang, Qian Niu, Yang Gao, and Dazhi Hou — University of Science and Technology of China

The anomalous Hall effect, originating from the Berry curvature in momentum space, typically manifests as a dipole behavior in magnetization. This implies that the anomalous Hall conductivity is parallel to the magnetization in most transport measurements. However, even in iron, the in-plane magnetization can also induce the anomalous Hall effect, which contradicts the predictions of the dipole term in a cubic lattice. This behavior can be understood within the framework of the Berry curvature multipole structure in magnetization space. In this work, we propose a paradigm to quantify the coefficients of the Berry curvature multipole by examining the angular dependence of the Hall resistivity, which matches well with first-principles calculations. Under certain conditions, the contribution of the magnetization multipole can even surpass that of the dipole term, dominating the AHE.

MA 27.2 Wed 15:15 H18

Orthogonal faraday effect in garnet — •Haolin Pan[1], Han Li[2], Qinhui Yang[2], and Dazhi Hou[1] — [1]University of Science and Technology of China, Hefei, China. — [2]University of Electronic Science and Technology of China, Chengdu, China.

Faraday effect, a transmissive magneto-optical phenomenon with a long history and diverse applications, has been be confined within parallel configuration between light and magnetization in experiments. This routine originates from the common assumption that the asymmetric components of dielectric tensor is in linear response to magnetization. However, our experiments in garnet materials reveal the nonlinear nature of Faraday effect with respect to magnetization orientation, which allows the orthogonal geometry between light and magnetization. The lattice angular dependence and spectroscopy results are in good agreement with theory of multipole structures of Berry curvatures in magnetization space. The observation of orthogonal Faraday effect provides new opportunities for magneto-optical studies and applications.

MA 27.3 Wed 15:30 H18

Strong anisotropy of quadratic magneto-optical Kerr effect in FeRh — •zeynab sadeghi, vladislav wohlrath, jozef kimák, peter kubaščík, eva schmoranzerová, tomas ostatnický, and petr němec — faculty of mathematics and physics, charles university, prauge, 121 16, czech republic

recently, we developed a technique that enables to measure magnetic anisotropy and anisotropy of quadratic magneto-optical Kerr effect (QMOKE) [1]. This technique is based on measurement of magneto-optical response in rotating magnetic field using series of incident light linear polarizations at normal incidence on the sample with a fixed position and, therefore, it can be applied also for samples placed in a cryostat. In this contribution, we report on measurements in FeRh, which is an interesting material with an antiferromagnetic (AFM) ordering at room temperature and a ferromagnetic (FM) phase at temperatures above 400 K. We show that in the FM phase QMOKE has a very strong wavelength-dependent anisotropy in the investigated spectral range from 460 nm to 1600 nm. We also discuss the possibility of investigation of the FeRh AFM phase using this technique. [1] wohlrath, w., sadeghi, z. et al. "quadratic magneto-optical Kerr effect spectroscopy: Polarization variation method for investigation of magnetic and magneto-optical anisotropies." arXiv:2409.20205 (2024).

MA 28: Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions

Time: Wednesday 15:00–17:30 Location: H19

MA 28.1 Wed 15:00 H19

Correlations of short-range environment and hyperfine parameters in disordered FeV thin-films — •Simon Rauls[1], Benedikt Eggert[1], Jürgen Fasbender[2], Kay Potzger[2], Rantej Bali[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf

The binary alloy $Fe_{1-x}V_x$ shows a variety of interesting properties, ranging from antiparallel coupling of induced V magnetic moments up to 1 μ_B per V atom to the positive vibrational entropy in the disorder/order transition from the A2 to the B2 bcc-crystalline phase. Furthermore, around equiatomic composition, the structurally complex σ-phase might develop. To understand these effects, the local atomic environment as well as both structural and chemical disorder need to be considered. Using Mössbauer spectroscopy, the local environment of ^{57}Fe atoms and different aspects of disorder can be investigated through careful analysis of the distribution of hyperfine parameters, i.e.. the hyperfine field splitting and the isomer shift. In this talk, the conversion electron Mössbauer spectra of the entire concentration range of $Fe_{1-x}V_x$ thin film samples are presentedd. Enrichment with 95% ^{57}Fe results in a very high signal to noise ratio, which allows for comparison of Hesse-Rübartsch fits with a model, in which the hyperfine parameters are described by a binomial distribution of the first three nearest-neighbor shells. We acknowledge funding by the DFG through project No. 322462997.

MA 28.2 Wed 15:15 H19

Simulating magnetostriction in skyrmion-hosting $MnSc_2S_4$ — •Justus Grumbach[1], Mahmood Deeb[1], Sergey Granovsky[1], Lilian Prodan[2], Vladimir Tsurkan[2], Martin Rotter[3], and Mathias Doerr[1] — [1]Institut für Festkörper- und Materialphysik, TU Dresden, 01062 Dresden — [2]Experimentalphysik V, Universität Augsburg, 86135 Augsburg — [3]*McPhase* Projekt, 01159 Dresden

Measurements of neutron scattering on $MnSc_2S_4$ explored an antiferromagnetic skyrmion state [1]. We measured the magnetostriction and found curves with characteristic anomalies. To find out which is linked to skyrmions, we performed mean field Monte Carlo simulations with the *McPhase* program package using the hamiltonian introduced earlier [1].

We could resemble main properties of the experimental outcome. The exact location of the skyrmionic state in the phase diagram and the discovery of a new 2$\boldsymbol{q}$ structure between the skyrmion state and saturation in field were new informations gained by these simulations.

Simulations and experimental results introduce a link of magnetostriction and skyrmions by a plateau-like non-distorted region, which could also be found in other compounds.

[1] S. Gao et al.: Fractional antiferromagnetic skyrmion lattice induced by anisotropic couplings. Nature, 586:37, 2020.

MA 28.3 Wed 15:30 H19

Tilted spin state near the spin reorientation of the topological kagome magnet Fe_3Sn_2 — •Lilian Prodan[1], Donald M. Evans[1,2], Aleksandr S. Sukhanov[1], Stanislav E. Nikitin[3], Alexander A. Tsirlin[4], Lukas Puntingam[1], Marein C. Rahn[1], Liviu Chioncel[1], Vladimir Tsurkan[1,5], and Istvan Kezsmarki[1] — [1]University of Augsburg, Augsburg, Germany — [2]Department of Sustainable Energy Technology, SINTEF Industry, Oslo, Norway — [3]Paul Scherrer Institut, Switzerland — [4]Leipzig University, Germany — [5]Moldova State University, Chisinau, Moldova

Spin reorientation due to competing magnetic anisotropies can have drastic effects on various physical properties in itinerant magnets with topologically nontrivial band structure. Therefore, understanding the mechanism of spin reorientation provides an efficient tool for engineering the properties of topological magnets [1]. Our target material is the topological kagome ferromagnet Fe_3Sn_2 [2], where we investigated the temperature-driven spin reorientation using a number of experimental techniques and numerical modeling. We reveal that the crossover from the high-temperature state with uniaxial easy-axis anisotropy to the low-temperature state with easy-plane anisotropy take place at ∼120 K through an intermediate tilted easy-cone state. Our MFM study highlights significant changes in the magnetic patterns emerging on the mesoscale across all three states, including the formation of magnetic bubbles on the surface of bulk centrosymmetric Fe_3Sn_2 crystals. [1] A. Kimel et.al, Nature 429, 850-853 (2004). [2] F. Schilberth et al., Phys. Rev. B 106, 144404 (2022).

MA 28.4 Wed 15:45 H19

High-field/high-frequency Ferromagnetic Resonance Studies on the van-der-Waals ferromagnet Fe_3GeTe_2 — •Birte Beier[1], Martin Jonak[1], Eva Brücher[2], Reinhard K. Kremer[2], and Rüdiger Klingeler[1] — [1]Kichhoff Institute for Physics, Heidelberg University, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Long-range ferromagnetic order develops down to the monolayer in Fe_3GeTe_2 and is particularly robust both in the monolayer and in the bulk as compared to other van-der-Waals ferromagnets. In the bulk, T_C amounts to about 220 K as compared to, e.g., 61 K in CrI_3 and 65 K in $Cr_2Ge_2Te_6$. In order to elucidate the origin of robust long-range ferromagnetism, we have investigated low-energy magnon excitations in Fe_3GeTe_2 by high-field/high-frequency ferromagnetic resonance studies. Our data reveal the size and temperature dependence of the anisotropy gap and also show the evolution of short-range magnetic order well above T_C. The frequency- and field-dependence of magnon excitation is discussed and compared with our recent findings on CrI_3 [1].

[1] M. Jonak *et al.*, Phys. Rev. B **106**, 214412 (2022)

MA 28.5 Wed 16:00 H19

Derivation of spin-orbit generated relativistic symmetric and antisymmetric exchange interactions — •Hiroshi Katsumoto[1], Yuriy Mokrousov[1,2], and Stefan Blügel[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099

Mainz, Germany

It has become clear that the higher-order exchange interactions beyond the Heisenberg interaction can promote very complex magnetic structures. Moriya derived the Dyzaloshinskii-Moriya interaction (DMI) for spin-1/2 systems, including spin-orbit coupling (SOC). We derived an expression that generates the DMI according to a systematic algorithm for any higher-order antisymmetric exchange interaction. Applying this expression to particular spin models consistently provides all recently suggested DMIs extended to higher-order exchange interactions [1]. In addition, it is found that in the second-order perturbation of SOC, not only the antisymmetric higher-order terms but also the symmetric spin-nematic term is obtained. The spin-nematic term is known to produce electromagnetic effects [2], and in this study, its microscopic derivation is given.
We acknowledge funding from the ERC grant 856538 (project "3D MAGIC") and DFG through SPP-2137 and SFB-1238 (project C1).
[1] 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).
[2] M. Soda *et al.*, PRL **112**, 127205 (2014)

MA 28.6 Wed 16:15 H19

magnetism and electronic dynamics in CuCr1-xSnxS4 — •Elaheh Sadrollahi[1], Cynthia P. C. Medrano[2], Magno A.V. Herling[2], Elisa M. Baggio Saitovitch[2], Lilian Prodan[3,4], Vladimir Tsurkan[3,4], and F. Jochen Litterst[5] — [1]IFMP, TU Dresden, 01069 Dresden, Germany — [2]CBPF, Rio de Janeiro, 22290-180, Brazil — [3]EKM, Inst. of Physics, University Augsburg, 86135 Augsburg, Germany — [4]IAP, Moldova State University, MD 2028, Chisinau, Republic of Moldova — [5]IPKM, TU Braunschweig, 38106 Braunschweig, Germany

Magnetization, muon spin rotation and relaxation(muSR), and 119Sn Mössbauer spectroscopy have been performed on the metallic ferromagnetic CuCr1-xSnxS4 (x=0.03-0.08) cubic spinel (Tc=360 K-343 K). Magnetization and muSR results reveal the same low-temperature magnetic transitions around 80 K and 40 K as found for the undoped material with a magnetic ground state deviating from a simple collinear ferromagnet [1] and proposed charge ordering [2]. The changes in Mössbauer hyperfine spectra are less pronounced and are discussed in view of the different positions of the local probes mu+ and 119Sn and their different magnetic coupling to the magnetic Cr lattice. Above 70 K, both muSR and Mössbauer spectra show temperature-dependent inhomogeneous broadening either due to structural or charge disorder and changing spin and charge dynamics that can be related to a precursor magnetic phase above the well-defined static low-temperature phase.
References: [1] E. Sadrollahi, et al., Phys. Rev. B 110, 054439 (2024). [2] K. Oda, et al., J. Phys. Soc. Jpn. 70, 2999 (2001).

15 min. break

MA 28.7 Wed 16:45 H19

Ground state magnetization in superstable graphs — •Fabio Pablo Miguel Méndez-Córdoba[1,2,3], Joseph Tindall[4], Dieter Jaksch[1,2,5], and Frank Schlawin[1,2,3] — [1]Universität Hamburg, Luruper Chaussee 149, Gebäude 69, D-22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg D-22761, Germany — [3]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, 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

Much of our understanding of ground state magnetic properties rests on analytical results on bipartite lattices. However, few exact results are known in non-bipartite graphs with frustrated couplings. We determine the ground state magnetization of strongly correlated systems on non-bipartite graphs displaying superstability. Superstability allows reinterpreting non-bipartite graphs as a collection of bipartite-connected components, providing magnetic properties of important lattices, such as the triangular ladder. Numerical evidence suggests further generalizations are feasible.

MA 28.8 Wed 17:00 H19

Magneto-optical spectroscopy on cubic noncollinear antiferromagnet HoCu — •Felix Schilberth[1,2], Marein Rahn[3], Andreas Bauer[4], Christian Pfleiderer[4], Sándor Bordács[2], and István Kézsmárki[1] — [1]Lst. für Experimentalphysik V, Universität Augsburg — [2]Dept. of Physics, BME Budapest — [3]Lst. für Experimentalphysik VI, Universität Augsburg — [4]Lst. für Experimentalphysik zur Topologie korrelierter Systeme, TU München

Giant anomalous Hall effect (AHE) and magneto-optical Kerr-effect (MOKE) can emerge in magnets with topologically non-trivial electronic bands. Besides extrinsic contributions from scattering of electrons by impurities, two intrinsic contributions are considered. In momentum space, the Berry curvature generated by non-trivial band features like Weyl points or nodal lines can produce resonances in the optical conductivity, leading to AHE in the static limit. On the other hand, noncollinear magnetic texture in the real space can induce topological Hall effect (THE). The separation of all three contributions is a remarkable experimental challenge which typically cannot be solved by magnetotransport experiments alone. Here, we address this question in the itinerant cubic antiferromagnet HoCu where a remarkably large AHE on the order of $10^6\,\Omega^{-1}\mathrm{cm}^{-1}$ was observed. By measuring reflectivity and MOKE, we determine the optical Hall effect spectrum, the finite frequency analog of the AHE. In this quantity, the energy scales provided by the scattering rate or the energy of band degeneracies allow to disentangle the AHE contributions by free carriers from interband resonances, decomposing this remarkable transport response.

MA 28.9 Wed 17:15 H19

Investigating the soft X-ray-induced spin-state switching in the room temperature regime of a Fe(II) spin-crossover complex — •Lea Kämmerer[1], Carolin Schmitz-Antoniak[2,3], Tobias Lojewski[1], Damian Günzing[1], Torsten Kachel[4], Florin Radu[4], Radu Abrudan[4], Katharina Ollefs[1], Senthil K. Kuppusamy[5], Mario Ruben[5,6], and Heiko Wende[1] — [1]University of Duisburg-Essen and CENIDE — [2]Forschungszentrum Jülich — [3]University of Applied Sciences Wildau, — [4]Helmholtz-Zentrum Berlin — [5]Karlsruhe Institute for Technology — [6]Institut de Science et d'Ingénierie Supramoléculaires

Spin-crossover complexes exhibit two distinct spin-states, designated as low-spin and high-spin, which are contingent upon the ligand field surrounding the central metal ion. It is possible to induce a switching of the spin state in these complexes through the use of soft X-rays. The complex $Fe(1-bpp-COOC_2H_5)_2(BF_4)_2CH_3CN$ exhibits an abrupt spin-state switching with an open thermal hysteresis around room temperature. Static X-ray absorption spectroscopy was performed at the synchrotron BESSY II, which allows for the analysis of the two spin states at the Fe $L_{2,3}$ absorption edges due to the presence of different fine structures. We gained insight into the cooperative mechanism that occurs during the soft X-ray-induced spin-state switching at room temperature. It was observed that once the effect was initiated in a thin film, a chain reaction led to further switching, even in the absence of soft X-rays. We thank the Deutsche Forschungsgemeinschaft for their financial support of the SFB 1242.

MA 29: Skyrmions II

Time: Wednesday 15:00–18:45 Location: H20

MA 29.1 Wed 15:00 H20

Emergent electromagnetic inductance of interface skyrmions in $SrRuO_3/SrIrO_3$ bilayers — •Ludwig Scheuchenpflug[1], Sebastian Esser[2], Robert Gruhl[1], Max Hirschberger[2,3], and Philipp Gegenwart[1] — [1]Universität Augsburg, Lehrstuhl für Experimentalphysik VI — [2]Department of Applied Physics, University of Tokyo, Japan — [3]RIKEN Center for Emergent Matter Science, Japan

Emergent electromagnetic induction (EEMI) by current-driven spin dynamics was proposed and observed in the spin helix magnet $Gd_3Ru_4Al_{12}$ [1], where the (current-nonlinear) imaginary impedance at kHz frequency was associated with the motion of helical spin structures. To explore the possibility of EEMI arising from current-driven skyrmion dynamics, we fabricated and microstructured epitaxial thin film bilayers of ferromagnetic $SrRuO_3$ and paramagnetic $SrIrO_3$ on $SrTiO_3$. This bilayer system is known to host DMI-stabilized Néel-skyrmions, indicated by the topological Hall-effect (THE) [2]. We reproduce the THE signatures and observe an accompanying large and current-linear imaginary impedance at low temperatures over broad current density and frequency ranges, signaling the EEMI from the low-energy dynamics of pinned interface skyrmions.

[1] Naoto Nagaosa, Jpn. J. Appl. Phys. 58, 120909 (2019), Yokouchi et al., Nature 586, 232 (2020).
[2] J. Matsuno et al., Science Adv. 2, e1600304 (2016), S. Esser et al., Phys. Rev. B 103, 214430 (2021).

MA 29.2 Wed 15:15 H20

Surface acoustic wave based movement of skyrmions — •Philipp Schwenke, Ephraim Spindler, Vitaliy Vasyuchka, Philipp Pirro, Abbass Hamadeh, and Mathias Weiler — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Magnetic skyrmions have significant potential for utilization in spintronic devices, primarily due to their stability and the ability to be manipulated by electric currents. However, when a current is applied, the skyrmions do not move in a direction parallel to the current flow due to the skyrmion Hall effect [1]. Consequently, the precise control of their movement is challenging. Recently, it has been demonstrated that a skyrmion can be moved using a surface acoustic wave (SAW) [2]. Here, we propose an alternative scheme for acoustic manipulation of magnetic skyrmions. Our approach is based on exploiting skyrmion pinning and non-sinusoidal SAWs. To demonstrate feasibility of our approach, we performed micromagnetic simulations using Mumax in a realistic pinning energy landscape.

[1] G.Chen *et. al*, Nature Phys. **13**, 112-113 (2017)
[2] Y.Yang *et. al*, Nat. Commun. **15**, 1018 (2024)

MA 29.3 Wed 15:30 H20

Quantum skyrmions and antiskyrmions in monoaxial chiral magnets — •Stefan Liščák, Andreas Haller, Andreas Michels, Thomas L. Schmidt, and Vladyslav Kuchkin — Department of Physics and Materials Science, University of Luxembourg

Classical monoaxial chiral magnets represent a unique magnetic system that allows for the stabilization of both skyrmions and antiskyrmions of equal energy. Unlike a similar situation in frustrated magnets, the energy landscape here is much simpler, consisting of four states: the saturated ferromagnetic state, spin-spiral, skyrmion, and antiskyrmion. This simplicity makes such systems interesting for potential applications that rely on manipulating these states. We study the quantum analog of the already established classical theory by investigating the low-excitation spectra of a spin-1/2 quantum Heisenberg model with monoaxial Dzyaloshinskii-Moriya interaction. We establish that such a model supports the existence of skyrmion and antiskyrmion states of equal energy using the density matrix renormalization group method (DMRG). This degeneracy allows for the existence of a mesoscopic Schrödinger cat state exhibiting properties of both skyrmion and antiskyrmion. To characterize this superposition, we calculate two-point correlation functions, which can be measured in neutron scattering experiments. Finally, we introduce a perturbation in the form of a magnetic field gradient to induce a non-trivial time evolution of the superposition state. We study this time evolution both using a numerical variational approach and the collective coordinates method.

MA 29.4 Wed 15:45 H20

Magnetometry on the low-temperature skyrmion state in Cu_2OSeO_3 — Christian Oberleitner[1], •Lukas Heindl[1], Johannes Friedrich[1], Andreas Bauer[1,2], Denis Mettus[1,3], Helmut Berger[4], and Christian Pfleiderer[1,2,3] — [1]Physik-Dep., TU Munich, D-85748 Garching — [2]ZQE, TU Munich, D-85748 Garching — [3]MLZ, TU Munich, D-85747 Garching — [4]Inst. de Phys., EPFL, CH-1015 Lausanne

In cubic chiral magnets, skyrmion lattice states emerge near the magnetic ordering temperature, stabilized by thermal fluctuations [1]. Recently, a distinct low-temperature skyrmion state (LTS) was observed in Cu_2OSeO_3 for magnetic fields along the $\langle 100 \rangle$ axes, emphasizing the role of cubic anisotropies [2, 3]. Nucleation of this state at low temperatures requires an intermediate phase, the tilted conical phase, and has been studied mainly along major crystallographic axes [4].

Here, we examine the nucleation dynamics of the LTS under field rotation away from high-symmetry directions. Magnetization and ac susceptibility measurements on spherical and cuboid samples reveal key geometry effects. Spherical samples, with uniform internal field distributions, show significant spontaneous LTS nucleation. In contrast, cuboid samples, with inhomogeneous internal fields, need external field pumping to achieve substantial LTS populations[5].

[1]: S. Mühlbauer et al., Science, 323 (2009) 915-919 [2]: S. Seki et al., Phys. Rev. B, 85 (2012) 220406(R) [3]: A. Chacon et al., Nat. Phys., 14 (2018) 936-941 [4]: M. Halder et al., Phys Rev., B 98 (2018) 144429 [5]: A. Aqeel et al., Phys. Rev. Lett., 126 (2021) 017202

MA 29.5 Wed 16:00 H20

Edge dislocations in helimagnets as mobile topological defects — •Maurice Colling[1], Manuel Zahn[1,2], Jan Masell[3], and Dennis Meier[1] — [1]NTNU Norwegian University of Science and Technology, Trondheim, Norway — [2]University of Augsburg (UniA), Augsburg, Germany — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Magnetic topological solitons, such as skyrmions and hopfions, represent fertile ground for emergent physical properties with potential applications in spintronics and unconventional computing. In my talk, I will present magnetic edge dislocations as intriguing nano-sized topological textures, which can serve as mobile information carriers. Edge dislocations naturally arise in the helimagnetic background of the B20-type material FeGe, which we study as a model system. Using micromagnetic simulations, we demonstrate how isolated dislocations can be initialized in a track-like geometry and how their movement can be controlled using spin-polarized currents and magnetic fields. Furthermore, we show how pinning sites can be introduced to achieve 'stop-and-go' motion, allowing to translate events (e.g. magnetic field or current pulses) into positional information. One key difference between dislocations and other topological solitons is their relaxation motion which is driven by the system's intrinsic tendency to revert toward the helimagnetic ground state. This feature makes them interesting candidates for sensing and computing applications and low-energy device technologies in general.

MA 29.6 Wed 16:15 H20

Cubic magnetic anisotropy in *B*20 magnets: Interplay of anisotropy and magnetic order in $Fe_{1-x}Co_xSi$ — •Gilles Gödecke, Julius Grefe, Stefan Süllow, and Dirk Menzel — Insitut für Physik der Kondensierten Materie, TU Braunschweig, D-38106 Braunschweig, Germany

The itinerant systems MnSi and $Fe_{1-x}Co_xSi$ are prominent members among the chiral *B*20 helimagnets. They are known to host chiral spin structures and magnetic skyrmions as a result from the competition of various magnetic interactions, one of which is magnetic anisotropy. Recently, a secondary skyrmion phase governed by cubic anisotropy was identified in the compound Cu_2OSeO_3 [1] raising the question wether such a phase also exists in MnSi and $Fe_{1-x}Co_xSi$. To aid the search for this phase, a better understanding of the cubic anisotropy in these systems would be beneficial.

Here, we report on the quantitative measurement of the cubic magnetocrystalline anisotropy constants in MnSi and $Fe_{1-x}Co_xSi$ ($0.08 \leq$

$x \leq 0.70$) single crystals. Our work presents a systematic study regarding the cubic anisotropy at $T = 5\,\mathrm{K}$ and $T = 10\,\mathrm{K}$ by means of angle-resolved SQUID magnetization measurements. We observe that the cubic anisotropy is generally weaker than in familiar compounds and more pronounced in MnSi than in $Fe_{1-x}Co_xSi$. For $Fe_{1-x}Co_xSi$ the anisotropy gains at low Co-concentrations with increasing x, vanishes for $x = 0.50$, and is then finite for high x.

[1] A. Chacon et al., Nature Physics 14, 936-941 (2018)

MA 29.7 Wed 16:30 H20

Imaging Topological Defect Dynamics Mediating 2D Skyrmion Lattice Melting — •Raphael Gruber[1], Jan Rothörl[1], Simon Fröhlich[1], Maarten Brems[1], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1], Elizabeth Martín Jefremovas[1], Sachin Krishnia[1], Asle Sudbø[2], Peter Virnau[1], and Msthias Kläui[1] — [1]Institute of Physics, JGU Mainz — [2]QuSpin, NTNU Trondheim

Two-dimensional (2D) phase transitions are mediated by topological defects, as predicted by KTHNY theory. Using real-time Kerr microscopy, we image the two-step melting of a 2D skyrmion lattice with high spatial and temporal resolution. Skyrmions in low-pinning thin-film systems offer tunability of their size and effective temperature [2,3], allowing us to controllably drive the phase transitions.

Our results reveal the emergence of an intermediate hexatic phase and identify topological defects as the key feature of the melting. We provide new insight into 2D melting dynamics and measure a dislocation diffusion coefficient orders of magnitude higher than skyrmion diffusion. This work highlights skyrmions as a versatile platform for studying phase behavior in 2D systems

[1] Kosterlitz & Thouless, J. Phys. C: Solid State Phys. 5, L124 (1972). [2] Zázvorka et al., Nat. Nanotechnol. 14, 658-661 (2019). [3] Gruber et al., Adv. Mater. 35, 2208922 (2023).

15 min. break

MA 29.8 Wed 17:00 H20

Imaging Topological Defect Dynamics Mediating 2D Skyrmion Lattice Melting — Maarten A. Brems[1], Tobias Sparmann[1], •Simon M. Fröhlich[1], Leonie-C. Dany[1], Jan Rothörl[1], Fabian Kammerbauer[1], Elizabeth M. Jefremovas[1], Oded Farago[2], Mathias Kläui[1], and Peter Virnau[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Ger many — [2]Biomedical Engineering Department, Ben Gurion University of the Negev, Be'er Sheva 84105, Israel

We demonstrate fully quantitative Thiele model simulations of magnetic skyrmion dynamics on previously unattainable experimentally relevant large length and time scales by ascertaining the key missing parameters needed to calibrate the experimental and simulation time scales and current-induced forces. Our work allows us to determine complete spatial pinning energy landscapes that enable quantification of experimental studies of diffusion in arbitrary potentials within the Lifson-Jackson framework. Our method enables us to ascertain the time scales, and by isolating the effect of ultra-low current density (order 10^6 A/m^2) generated torques we directly infer the total force acting on the skyrmion for a quantitative modelling. [2]

[1] S. Lifson and J. L. Jackson, J. Chem. Phys. 36, 2410 (1962). [2] M. A. Brems et al., Phys. Rev. Lett., (2024) (accepted for publication)

MA 29.9 Wed 17:15 H20

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]Institut für Physik, Universität Augsburg

When magnetic skyrmions decay, their size in real space decreases in a finite time before they eventually collapse. We derive a continuum model to describe the shrinking behavior of skyrmions before they collapse. Using the Landau-Lifshitz-Gilbert equation and the time derivative of the vectorfield, we find a set of coupled nonlinear ordinary differential equation for the time dependent skyrmion radius and helicity. In particular, we use a triangular-shaped skyrmion profile of its polar angle. Contrary to the commonly expected simple exponential decrease in size, we reveal a more complicated time dependence, where the time-dependent radius crosses over from an exponential decay towards a square root decrease, $\sim (t - t_c)^{1/2}$, near a critical time t_c at which it collapses. This critical time is found to depend logarithmically on the lattice constant. Additionally, we present studies examining the interplay between the shrinking and a transformation through different skyrmion configurations, depending on the various system parameters. The findings are accompanied by numerical studies, supporting the predictions from the theoretical continuum model.

MA 29.10 Wed 17:30 H20

Effects of chiral polypeptides on skyrmion stability and skyrmion diffusion — Fabian Kammerbauer[1], Yael Kapon[2], •Theo Balland[1], Shira Yochelis[2], Sachin Krishnia[1], Yossi Paltiel[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Institute of Applied Physics, Faculty of Sciences, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel

CISS, chirality-induced spin selectivity is a phenomenon that has raised significant interest due to the large spin polarizations generated by organic molecules and other effects such as magnetic switching of ferromagnets induced by chiral molecules [1]. In hybrid systems, these chiral molecules have been observed to influence magnetic properties such as changes in the magnetization [2]. In this study, we investigate how chiral molecules of α-helix polyalanine interact with chiral spin structures, namely magnetic skyrmions, which are stabilized in ferromagnetic/heavy metal multilayers due to Dzyaloshinskii-Moriya interaction [3]. Using magneto-optic Kerr effect imaging, we show that chiral polypeptides can influence the stability of skyrmions by modifying the ranges of temperature and applied magnetic field in which they are stable. We also show that the chiral molecules affect the skyrmion dynamics, in particular the thermal diffusion of the skyrmions [4].

[1] R. Naaman et al. Nat. Rev. Chem. 3, 250 (2019)
[2] Y. Kapon et al. J. Chem. Phys. 159, 064701 (2023)
[3] K. Everschor-Sitte et al. J. Appl. Phys. 124, 240901 (2018)
[4] Y. Kapon et al. (under review)

MA 29.11 Wed 17:45 H20

Interactions between Skyrmions with various topological charges — •László Udvardi and Mátyás Török — Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary

Magnetic Skyrmions exhibit intriguing and novel phenomena due to their topologically non-trivial spin textures. Their exceptional stability makes them possible candidates for information carriers for future spintronic devices.

We have determined the parameters appearing in a classical spin model from first principle for a FePd bilayer on Ir(111) and $Pt_{95}Ir_{05}$/Pd(111) overlayer. Optimizing the energy of the spin model several local minima have been identified as a Skyrmion with various topological charges. We demonstrate that the frustration of the isotropic exchange interactions is responsible for the creation of these various types of skyrmionic structures. We focused on objects with topological charge of Q=-1 (Skyrmion) and Q=1 (anti Skyrmion) and explored the interactions between them. We found that although the interaction between Skyrmions with Q=-1 is always repulsive it has attractive part between anti Skyrmions. The excitation of an isolated Skyrmion and a lattice has been also investigated.

MA 29.12 Wed 18:00 H20

RC circuit based on magnetic skyrmions — •Ismael Ribeiro de Assis, Ingrid Mertig, and Börge Göbel — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

Skyrmions are nano-sized magnetic whirls attractive for spintronic applications due to their innate stability. They can emulate the characteristic behavior of various spintronic and electronic devices such as spin-torque nano-oscillators, artificial neurons and synapses, logic devices, diodes, and ratchets. Here, we show that skyrmions can emulate the physics of an RC circuit*the fundamental electric circuit composed of a resistor and a capacitor*on the nanosecond time scale. The equation of motion of a current-driven skyrmion in a quadratic energy landscape is mathematically equivalent to the differential equation characterizing an RC circuit: the applied current resembles the applied input voltage, and the skyrmion position resembles the output voltage at the capacitor. These predictions are confirmed via micromagnetic simulations. We show that such a skyrmion system reproduces the characteristic exponential voltage decay upon charging and discharging the capacitor under constant input. Furthermore, it mimics the low-pass filter behavior of RC circuits by filtering high-frequencies in periodic input signals. Since RC circuits are mathematically equivalent to the Leaky-Integrate-Fire (LIF) model widely used to describe biological neurons, our device concept can also be regarded as a perfect artificial LIF neuron.

MA 29.13 Wed 18:15 H20

Intrinsic non-reciprocity in skyrmion dynamics in synthetic antiferromagnet — •Mona Bhukta[1], Takaaki Dohi[1], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1,2], Duc Minh Tran[1], Markus Weigand[3], Sebastian Wintz[3], Simone Finizio[4], Jörg Raabe[4], Robert Frömter[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Singulus Technologies AG, 63796 Kahl am Main, Germany. — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 14109 Berlin, Germany — [4]Paul Scherrer Institut, Swiss Light Source, Forschungsstrasse 111 5232 PSI Villigen, Switzerland.

In this work, we investigate the dynamics of isolated AFM skyrmion tubes in synthetic antiferromagnetic (SyAFM) multilayers composed of 30-50 ferromagnetic (FM) layers, antiferromagnetically coupled via the interlayer exchange interaction. Using element-specific time-resolved scanning transmission X-ray microscopy (STXM), we demonstrate the current-induced dynamics of the resulting AFM skyrmions. In uncompensated SyAFM, we observe a current-polarity-dependent, nonreciprocal skyrmion Hall effect of individual AFM skyrmions, arising from the unique intrinsic properties of the hybrid chiral skyrmion tubes in the flow regime. This nonreciprocity can be tuned by the degree of magnetic compensation and vanishes in highly compensated SyAFM [1]. References [1] T. Dohi, M. Bhukta, et al., Observation of a nonreciprocal skyrmion Hall effect of hybrid chiral skyrmion tubes in synthetic antiferromagnetic multilayers,arxiv (2024).

MA 29.14 Wed 18:30 H20

Hybrid magnonic crystal based on skyrmions — •Krzysztof Szulc[1,2], Mateusz Zelent[2], and Maciej Krawczyk[2] — [1]Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland — [2]ISQI, Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznań, Poland

We study a hybrid magnonic crystal consisting of a Py waveguide over which the periodic chain of Co/Pt dots is placed [K. Szulc et al. arXiv:2404.10493]. In the dots, the Dzyaloshinskii-Moriya interaction is present, thus it is possible to stabilize the single-domain state and the skyrmion state. We show that the dispersion relation changes with the change of the magnetization configuration of the dot. The sizes of bandgaps significantly differ in these systems. Due to different character of excitation of the both states, the system with skyrmions in dots can interact with the waveguide at lower frequencies or even be excited below the frequencies of the waveguide. Furthermore, I show that one part of the skyrmion modes hybridize with the waveguide modes, sometimes inducing additional band gaps in the spectrum, while the second part does not interact, forming bound states. Such a system of waveguide coupled to the chain of dots forms a reconfigurable spin-wave platform which can be used in spin-wave filtering and artificial neural networks.

This work was supported by the National Science Centre, Poland, grant no. UMO-2021/41/N/ST3/04478 and EU Research and Innovation Programme Horizon Europe (HORIZON-CL4-2021-DIGITAL-EMERGING-01) under grant agreement no. 101070347 (MANNGA).

MA 30: Bulk Materials: Soft and Hard Permanent Magnets

Time: Wednesday 16:00–18:00 Location: H18

Invited Talk MA 30.1 Wed 16:00 H18

Boosting Coercivity in Additively Manufactured Magnets Through Nano-Functionalization of NdFeB Powder — •Anna Ziefuss — Technical Chemistry I and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg Essen, 45141 Essen, Germany

Permanent magnets are indispensable in the 21st century, powering applications in energy generation, transportation, and telecommunications. However, the high cost of rare-earth magnets, their supply, and availability represent critical factors, and novel technologies that avoid or minimize the use of such rare elements in permanent magnets need to be developed immediately. Additive manufacturing (AM) offers a promising solution by enabling complex structures with minimal material waste, reducing rare-earth usage. Yet, the successful printing of magnetic powders remains challenging, as printed magnets often exhibit brittleness and low magnetic properties. This contribution highlights how nanotechnology-driven innovations address limitations in additive manufacturing, unlocking the potential of printed magnets for sustainable, high-performance applications. Nano-functionalization emerges as a crucial approach to enhancing coercivity in additively manufactured magnets, emphasizing the importance of understanding the entire process chain - from nanoparticle production and feedstock modification to evaluating printed magnet properties.

MA 30.2 Wed 16:30 H18

Strategies for Nd-Fe-B Magnet Recycling in a Circular Economy — •Aybike Paksoy[1], Amrita Khan[1], Abdullatif Durgun[1], Mario Schönfeldt[1,2], Mahmudul Hasan[2], Iliya Radulov[2], Jürgen Gassmann[2], Imants Dirba[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Department of Materials and Geosciences, Functional Materials, Peter-Grünberg-Str. 16, 64287 Darmstadt, Germany — [2]Fraunhofer IWKS, Fraunhofer Research Institution for Materials Recycling and Resource Strategies, Aschaffenburger Str. 121, 63457 Hanau, Germany

Nd-Fe-B magnets have the highest energy product (BH)max at room temperature, making them the preferred material for various applications. However, their reliance on critical rare earth elements raises significant environmental, economic, and geopolitical challenges, particularly due to China's dominance as the primary global supplier. Both industry and academia are increasingly focusing on recycling end-of-life 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 [1]. We compare three advanced recycling routes to produce sustainable Nd-Fe-B magnets without sacrificing their performance. Scrap magnet material is processed via the hydrogen-assisted magnet-to-magnet route as well as the nanocrystalline hot pressing route and spark plasma sintering. The resultant magnetic properties and microstructure are systematically studied comparing the advantages and disadvantages of each process. [1] M. Schönfeldt et al., J. Alloys and Compounds (2023)

MA 30.3 Wed 16:45 H18

3D magnetic of interaction domains in nanostructured Nd-Fe-B using X-ray imaging techniques — •P. Klassen[1], D. Günzing[2], A. Aubert[3], T. Feggeler[4], B. Eggert[1], J. Neethirajan[5], L. Schäfer[3], F. Maccari[3], M. Guizar-Sicairos[6,7], V. Scagnoli[8,6], M. Holler[6], D. Shapiro[2], A. Ditter[2], E. Bruder[3], H. Wende[1], K. Skokov[3], O. Gutfleisch[3], C. Donnelly[5], and K. Ollefs[1] — [1]Fac. of Phys., UDE, Duisburg GER — [2]LBNL, ALS, CA US — [3]Mat. Sc., TU Darmstadt GER — [4]BNL, NSLS-II, NY US — [5]MPI CPfS, Dresden GER — [6]PSI, SLS, Villigen CH — [7]Inst. of Physics, EPFL, Lausanne CH — [8]Dep. of Mat., ETH Zürich CH

Nd-Fe-B magnets play a key role in sustainable energy conversion, for example in wind turbines or electric motors, due to their superior magnetic performance and high energy density. Here, we provide insights into the 3D magnetic domain structure of (therm.) demagnetized nanostructured Nd-Fe-B magnets obtained by X-ray ptychography and tomography at room temperature. We have imaged the magnetic interaction domains inside a hot-deformed, anisotropic, nanocrystalline Nd2Fe14B magnet to correlate the crystal and microstructure and the configuration of the magnetic moments. The combination of hard and soft X-rays enables the comparison of the domain structure between bulk and lamellae and provides detailed insights into the complex magnetic structure in deeper sections of the magnet and down to individual grains, which can be shown to partly exhibit a single-domain state. We gratefully acknowledge funding from the DFG via CRC/TRR 270.

MA 30.4 Wed 17:00 H18

Combined theoretical and experimental study of magnetic properties of Fe-Sn intermetallics — •Martin Friák[1], Petr Čípek[1,2], Pavla Roupcová[1], Oldřich Schneeweiss[1], Jana Pavlů[2], Dominika Fink[3], Šárka Msallamová[3], and Alena

Michalcová[3] — [1]Inst. Phys. Mater., Czech Acad. Sci., Brno, Czech Rep. — [2]Dept. Chem., Masaryk Uni., Brno, Czech Rep. — [3]Dept. Metal Corr. Eng., Uni. Chem. Technol. Prague, Czech Rep.

There are conflicting literature reports related to Fe-Sn intermetallic phases, when, for example, the $FeSn_2$ phase is theoretically predicted to be dynamically unstable due to imaginary phonon modes (see, e.g, C.-J. Yu et al., New J. Chem. 44 (2020) 21218, DOI:10.1039/d0nj04537c). We have, therefore, performed a combined theoretical and experimental study of both $FeSn_2$ and FeSn intermetallics. The theoretical part consists of quantum-mechanical calculations of ground-state properties, including structural, vibrational and magnetic properties. Computing phonon modes allowed for testing the dynamic stability and the thermodynamic properties were subsequently assessed using quasi-harmonic approximation (QHA). The $FeSn_2$ phase is computed stable, i.e., free of imaginary phonon modes. We have also characterized Fe-Sn phases using Mössbauer measurements of magnetic properties, including a temperature-dependent Mössbauer factor, which we compared with theoretical results based on quantum-mechanical calculations of thermal vibrations.

MA 30.5 Wed 17:15 H18

Pr-Fe-B hot deformed magnets for low-temperature applications — •Priyatosh Sahoo[1], Alex Aubert[1], Fernando Maccari[1], Yuye Wu[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt, Germany — [2]Beihang University, China

Nd-Fe-B based PMs are the most prevalent in various applications due to their high coercivity and remanence, which result in exceptional energy product values near room temperature. However, their performance significantly diminishes below 135 K due to Spin Reorientation Transition (SRT). In contrast, when Nd is substituted by Pr, these magnets do not exhibit such transitions at low temperatures, making them preferable for cryogenic applications such as space industry. In our study, we compared the low-temperature performance of Pr17Fe76.5Cu1.5B5 and Nd17Fe76.5Cu1.5B5 hot deformed (HD) magnet. The microstructure of HD magnets consists of grains in the range of the critical single domain particle size of these systems, i.e., 200-300 nm, which enhances coercivity without the necessity of adding heavy rare earth elements. We conducted a comprehensive analysis that examined intrinsic magnetic properties based on single crystal studies and the transition to extrinsic properties through microstructure engineering along the hot deformation process. Additionally, we explored the effect of doping Pr-Fe-B with Cu in the hot deformation process and correlated its influence on the magnetic properties and microstructure. We acknowledge Deutsche Forschungsgemeinschaft's (DFG) funding within the CRC/TRR 270 (Project-ID 405553726).

MA 30.6 Wed 17:30 H18

Peculiar low-temperature properties in the ferromagnetic pyrochlore metal $LuInCo_4$ — •Taiki Shiotani[1], Hiroyuki Nakamura[1], and István Kézsmárki[2] — [1]Department of Materials Science and Engineering, Kyoto University, Kyoto 606-8501, Japan — [2]Experimental Physics V, Institute of Physics, University of Augsburg, D-86159, Augsburg, Germany

The pyrochlore lattice, a network of corner-sharing tetrahedra, is attracting attention due to geometrical frustration as well as nontrivial topology of the band structure. $LuInCo_4$ is C15b-type laves phase compound with a Co-based pyrochlore sublattice. We have successfully synthesized single crystals of $LuInCo_4$ and found strong ferromagnetism with the $T_C = 306$ K [1]. The ferromagnetic nature was reproduced by density functional theory calculations, suggesting that Co-3d flat bands near the fermi level induce the spin polarization. The magnetization has no detectable anisotropy down to ≈100 K, below which the anisotropy gradually becomes stronger with the cubic 100-type axes being the easy-axes. For fields applied along the cubic 111-type directions the material goes through a metamagnetic transition.

Here, we will focus on the low-temperature phase of $LuInCo_4$ to discuss the origin of the anomalous behavior of the magnetization.

[1] T. Shiotani *et al.*, Phys. Rev. Mater. 8, 114409 (2024)

MA 30.7 Wed 17:45 H18

Laser powder bed fusion of hard magnetic composites — •Kilian Schäfer — Functional Materials, Institute of Material Science, Technical University of Darmstadt

Hard magnetic materials are essential for advancing carbon-neutral technologies and medical devices. While traditional manufacturing methods suit large, simple magnets, there is increasing demand for resource-efficient processes to create intricate small magnetic components. Additive manufacturing offers a promising solution, enabling the production of complex, tailored magnetic components with improved efficiency. This study explores composites made via laser powder bed fusion, combining hard magnetic powders with polyamide and thermoplastic polyurethanes. It examines how the magnetic powder*s fraction, morphology, and particle size impact performance. Results show that anisotropic magnetic properties can be achieved with specific powder particle shapes. Additionally, localized mechanical properties were achieved by adjusting laser parameters, enabling the production of magnetically controllable actuators for applications like biomedical devices. These findings provide guidelines for optimizing hard magnetic composite performance using laser powder bed fusion.

MA 31: Poster II

Time: Wednesday 17:00–19:30 Location: P1

MA 31.1 Wed 17:00 P1

Near-Room-Temperature Compensation Temperature In Terbium Iron Garnet Thin Films — •Mehak Loyal, Akashdeep Akashdeep, Mathias Kläui, and Gerhard Jakob — Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany

Rare-earth iron garnets (REIGs) with perpendicular magnetic anisotropy (PMA) have emerged as promising materials for spintronic applications. The compensation temperature (T_{comp}), where the net magnetization for the ferrimagnet becomes zero, plays a crucial role in determining potential application. While bulk REIGs have a T_{comp} well below room temperature, researchers have shown that it can be tuned in thin films. $Tb_3Fe_5O_{12}$ (TbIG) with bulk compensation temperature ∼240 K, in particular has gained interest as recent report shows a near-room-temperature T_{comp} for TbIG thin films.

We investigate the factors that tune the compensation temperature (T_{comp}) of TbIG thin films to near-room-temperature. This would have significant implications for the development of spintronics applications, potentially enabling more efficient and stable operation at ambient conditions. PMA TbIG thin films are deposited on (111)-oriented $Gd_3Ga_5O_{12}$ (GGG) substrates using pulsed laser deposition (PLD). The magnetization reversal of TbIG thin films at different temperatures are probed using transverse magneto-resistance measurement. The study contributes to the broader understanding of REIGs and paves the way for integration into practical spintronic applications.

MA 31.2 Wed 17:00 P1

Polarized inelastic neutron scattering studies on magnetic excitations in the SDW ordered state of qasi 2D $Sr_{1.5}Ca_{0.5}RuO_4$ — •Felix Wirth[1], Yvan Sidis[2], Paul Steffens[3], and Markus Braden[1] — [1]II. Physic. Inst., Univ. Cologne, Germany — [2]LLB, CEA Saclay, France — [3]ILL, Grenoble, France

Superconductivity in the layered ruthenate Sr_2RuO_4 emerges near competing magnetic fluctuations. The different d orbitals of Ru^{4+} give rise to the multi-band structure causing spin fluctuations with incommensurate (IC) propagation vector due to fermi-surface nesting. These antiferromagnetic fluctuations are anisotropic and condensate to static spin density wave (SDW) order with moments oriented along c when Sr is replaced by 25 % of isovalent Ca. Only a few realizations of SDW in metals have been studied concerning their magnetic excitations. Cr exhibits strong anisotropy as well as new excitations like the Fincher-Buke mode, while the spin-orbit coupling (SOC) is much smaller than in $Sr_{1.5}Ca_{0.5}RuO_4$. This renders it an ideal material for studying SDW state in the presence of SOC. Our contribution presents inelastic polarized neutron scattering measurements on the IC SDW signal. With scattering vector within the layer, we discriminated between transversal and longitudinal excitations. We see longitudinal or c-polarized spectral weight enhancement at low energy. At the same time, the transversal or in-plane response is suppressed over a broad temperature range and exhibits single-relaxor behavior like in the pure compound. SOC induces strong anisotropy in the magnetic fluctuations in $Sr_{1.5}Ca_{0.5}RuO_4$.

MA 31.3 Wed 17:00 P1

Structural and magnetic properties of Bi-bonded Mn-Al-C-Ti magnets — •Semih Ener, Fernando Maccari, Konstantin P. Skokov, and Oliver Gutfleisch — Functional Materials, Technical University of Darmstadt, Peter-Grünberg-Str. 16, D-64287, Darmstadt, Germany

In this study, the influence of Ti doping on the phase formation and magnetic properties of Mn-Al-C-Ti alloys is investigated. The alloys were synthesized by melt spinning followed by thermal treatment to obtain the ferromagnetic τ-phase, which was determined to be 20 min at 550 °C for all Ti compositions.

However, the Ti-doped samples exhibited β-phase formation due to partial phase decomposition, with TiC precipitates observed at higher Ti concentrations. Doping resulted in an increase in the Curie temperature from 557 K in the undoped sample to 600 K in the Ti-doped samples.

In order to increase the coercivity, a combination of ball milling and hot compaction was used along with the introduction of Bi as a metallic binder. This resulted in an increase in coercivity, from 0.18 T to 0.33 T, as the addition of Bi facilitated the formation of a grain boundary phase, which aided in densification. This work demonstrates how compositional and processing modifications can be used to improve the magnetic properties of Mn-Al based magnets.

[1] J.S. Trujillo Hernández, F. Maccari, J.A. Tabares, K.P. Skokov, G.A. Pérez Alcázar, O. Gutfleisch and S. Ener, J. Magn. Magn. Mater. 610 (2024) 172573.

MA 31.4 Wed 17:00 P1

Comparative study on magenetical and structural properties Mn_3XC (X=Sn,Ga,In,Zn) antiperovskites — •Lennart Endler, Benedikt Eggert, Katharina Oleffs, Mehmet Acet, and Heiko Wende — Faculty of Physics and CENIDE, University of Duisburg-Essen

The family of Mn_3XC antiperovskites shows a wide variety of properties ranging from large magnetocaloric effects, giant magnetoresistance to negative thermal expansion [1], which makes them an interesting material class for researchers and industry. Starting with ternary compounds, we also investigate the effect of multiple elements on the X-site, as done for perovskite oxides in the past, revealing a correlation between Neel temperature and Goldschmidt tolerance factor and therefore the chosen elements [2]. For the chemical, structural and magnetic characterisation, we have used EDX, X-ray diffraction, magnetometry and if possible ^{119}Sn Mössbauer spectroscopy. Based on the analysis of the ternary compounds prepared by solid state reaction, the foundation for a comparison to medium and high entropy Mn-antiperovskites is held to further explore and potentially control their properties.

We acknowledge the financial support through the Deutsche Forschungsgemeinschaft wihtin the framework of the CRC/TRR270 HoMMage (Project 405553726-TRR270).

[1] Y. Wang, Adv. Mater. 32, 1905007 (2020)
[2] R. Witte, Phys. Rev Mat. 3, 034406 (2019)

MA 31.5 Wed 17:00 P1

Effect of Ni addition to Fe-B-Si-Nb alloy on magnetic and thermal properties — •Purbasha Sharangi[1], Uma Rajput[2], Amirhossein Ghavimi[2], Ralf Busch[2], Isabella Gallino[3], Gabriele Barrera[1], Enzo Ferrara[1], and Paola Tiberto[1] — [1]INRIM, Istituto Nazionale di Ricerca Metrologica, Strade delle Cacce, 5, 10135 Torino, Italy. — [2]Saarland University, Chair of Metallic Materials, Campus C6.3 66123, Saarbrücken, Germany — [3]Technical University of Berlin, Chair of Metallic Materials, Ernst-Reuter Platz 1, 10587 Berlin, Germany

The next generation of electrical equipment, such as motors and generators, and power electronics, depend heavily on soft magnetic materials. It has been reported that the addition of Ni to Fe-Si-B-Nb BMGs has shown significant improvements in both their soft magnetic properties and plasticity. Fe-based BMGs that incorporate Ni exhibit a good glass forming ability (GFA), reasonable soft magnetic properties and improved mechanical performance. In this work we have investigated the effect of Ni addition and annealing on the microstructural, thermal and magnetic properties of Fe-B-Si-Nb alloy. It has been observed that the GFA is improved from 800 μm to almost 1000 μm upon the addition of 2 to 5 at. % Ni. A slight increment in saturation magnetization and reduction in coercive field have been observed with increasing the Ni% for the as cast ribbons. Further, the soft magnetic properties improve significantly in the form of reduced coercivity and energy losses after annealing the ribbons at 320 °C for 2 hours due to the relief of frozen-in stresses.

MA 31.6 Wed 17:00 P1

A materials library for cryogenic magnetocaloric cooling — •T. Gottschall, E. Bykov, M. Strassheim, T. Niehoff, C. Salazar-Mejía, and J. Wosnitza — Helmholtz-Zentrum Dresden-Rossendorf, Dresden High Magnetic Field Laboratory (HLD), Dresden, Germany

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. Originally, magnetic cooling was used to achieve ultra-low temperatures near absolute zero. Recently, low temperatures have once again become the focus of attention as an area of application for magnetocaloric cooling namely for efficient hydrogen liquefaction. In this contribution, we will present our materials library for cryogenic applications. The basis for this is our research infrastructure at the Dresden High Magnetic Field Laboratory, which includes both static and pulsed fields. Our aim is to gain a better understanding of the magnetocaloric materials required for the cooling process, to provide consistent data sets for simulations, and to drive magnetic hydrogen liquefaction forward making it an energy efficiency alternative to conventional technology.

MA 31.7 Wed 17:00 P1

Inverse magnetocaloric effect in Tb_3Ni: So hot right now — •T. Niehoff[1,2], B. Beckmann[3], K. Skokov[3], A. Herrero[4], A. Oleaga[5], M. Strassheim[1,2], T. Wosnitza[1,2], and T. Gottschall[1] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Dresden, Germany — [3]Institut für Materialwissenschaft, TU Darmstadt, Darmstadt, Germany — [4]Departamento de Física Aplicada, UPV/EHU, Vitoria-Gasteiz, Spain — [5]Departamento de Física Aplicada, UPV/EHU, Bilbao, Spain

The magnetocaloric effect (MCE) is a cornerstone of promising, environmentally friendly cooling technologies, particularly for cryogenic applications. In this presentation, we use Tb_3Ni as a case study, previously reported to exhibit a strong inverse MCE at very low temperatures based on magnetization measurements. By comparing these findings with other techniques, we show that neither Tb_3Ni nor similar materials with metamagnetic transitions from antiferromagnetic to ferromagnetic exhibit the predicted inverse effect. To support our claims and further investigate the MCE, we conducted specific-heat measurements and direct T_{ad} in pulsed-field experiments. These reveal no effects, while the pulsed-field data even show a significant positive effect, which we attribute to dissipative heating. Our findings highlight the importance of using complementary measurement techniques to accurately characterize the MCE and fully understand the behavior of these materials.

MA 31.8 Wed 17:00 P1

Design of $Cr_xFe_{1-x}MnCoNiGeSi$ high-entropy alloy with large barocaloric effect — •Yong Guo[1,2], Yuanyuan Gong[1], Tingting Zhang[1], Zhishuo Zhang[1], Bin Chen[1], Fenghua Chen[3,4], Zhengyi Jiang[4], Feng Xu[1], and Luana Caron[2,5] — [1]MIIT Key Laboratory of Advanced Metallic and Intermetallic Materials Technology, School of Materials Science and Engineering, Nanjing University of Science and Technology , Nanjing 210094, PR China — [2]Faculty of Physics, Bielefeld University, Bielefeld 33501, Germany — [3]School of Materials Science and Engineering, Taiyuan University of Science and Technology, Taiyuan 030024, PR China — [4]School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Wollongong, NSW 2522, Australia — [5]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany

This paper presents a high-entropy system exhibiting a large barocaloric effect. Experimental results confirm that equiatomic FeMnCoNiGeSi and CrMnCoNiGeSi are high-entropy solid-solutions with hexagonal and orthorhombic structures at room temperature, respectively. Further tuning Fe/Cr ratio in $Cr_xFe_{1-x}MnCoNiGeSi$ establishes a thermal-induced hexagonal-orthorhombic structural transformation. For the alloy with $x = 0.44 - 0.50$, the structural transformation occurs at room temperature and can be induced by hydrostatic pressure. The barocaloric effect reaches -30.6 J/kgK for a pressure change from 5 to 0 kbar, and the entropy change per kbar is comparable to widely studied intermetallic compounds.

MA 31.9 Wed 17:00 P1

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

Periodic stripe domain structures in thin films with perpendicular magnetic anisotropy are well-studied, however, the detailed field reversal of such systems in the transition regime between in-plane (IP) and out-of-plane (OOP) magnetization remains intriguing, with unexpected effects. In particular, the $[Co(3.0 nm)/Pt(0.6 nm)]_X$ multilayer system undergoes this transition[1]. We examine samples with $X = 10$ and $X = 11$ repetitions, which display a remanent state with both significant OOP as well as IP magnetization components, here referred to as the "tilted" stripe domain state[1,2]. Using vibrating sample magnetometry, magnetic force microscopy, and micromagnetic simulations, we analyze the unusual OOP field reversal behavior, which is characterized by a single point of irreversibility and parallel stripe domains at remanence. While these two characteristics seem at first sight mutually exclusive, we will reveal how they still can evolve simultaneously. In addition to the unusual OOP reversal, we also observe a significant IP angular dependence of the susceptibility around remanence induced by the parallel stripe domain alignment.

[1][L. Fallarino et al., Phys. Rev. B 99, 024431 (2019)]
[2][P. Heinig et al., Phys. Rev. B 110, 024417 (2024)]

MA 31.10 Wed 17:00 P1

Epitaxy and Magnetic Properties of Fe films on GaAs(001) in Dependence of the Electrodeposition Procedure — •Danny P. Quint[1], Raphael Kohlstedt[2,3], Olav Hellwig[2,3], and Karin Leistner[1] — [1]Institute of Chemistry, TU Chemnitz — [2]Institute of Physics, TU Chemnitz — [3]Research Center MAIN, TU Chemnitz

Epitaxial Fe/GaAs heterostructures are of great interest for spintronic devices.[1] The quality of the epitaxial growth is crucial for the functionality. While MBE is traditionally used to fabricate Fe/GaAs structures, electrodeposition (ED) offers a cost-efficient alternative. [2,3] We systematically examined the impact of an initial voltage pulse during ED of Fe films (approx. 20 nm thick) on GaAs(001) on their epitaxy and magnetic behavior. We compare depositions without a pulse (A), with a pulse after immersion in the electrolyte (B), and with a pulse during immersion in the electrolyte (C). The angle-dependent ferromagnetic resonance field, remanence and coercivity of the deposited films were analyzed by in-plane FMR and MOKE, respectively. The results show an enhanced fourfold anisotropy for the films prepared with the pulsed routines, with method C approaching the expected behavior for dominating cubic magnetocrystalline anisotropy in epitaxial Fe(001) films. The quality of epitaxial growth is investigated by X-ray diffraction. This work highlights the importance of optimizing the ED procedure to achieve epitaxial Fe films on GaAs and opens pathways for the broader application of ED in spintronic materials research. [1] Wastlbauer et al., Adv. Phys., 54, 2005, 137. [2] Liu et al., ESL, 7, 2004, D11. [3] Guo et al., Nano Lett., 22, 2022, 4006.

MA 31.11 Wed 17:00 P1

Pt-catalyzed hydrogen magneto-ionics in Co/Pd multilayers — •Felix Engelhardt[1,2], Rico Ehrler[1,2], Olav Hellwig[1,2], Karin Leistner[1,2], and Markus Gössler[1] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Research Center MAIN, D-09126 Chemnitz, Germany

Magneto-ionics, which is the electrochemical reconfiguration of magnetic materials at low gating voltages, offers a highly energy-efficient method to control magnetism. One major issue of this mechanism, however, is its response time, which is limited by the timescale of the electrochemical reactions. Here, we demonstrate that the hydrogen-based magneto-ionic effect in sputtered Co/Pd multilayers [1] can be accelerated catalytically via an additional Pt layer at the surface.

We investigate how the thickness of such a Pt overlayer affects the magneto-ionic effect strength and hydrogen insertion kinetics in the Co/Pd multilayer system. To analyze these effects, we use in-situ MOKE microscopy to monitor the magneto-ionic behavior, while flow-cell coulometry measurements are carried out to quantify the hydrogen concentration in the multilayers.

Our findings reveal that a Pt overlayer with a thickness of 0.5-2 nm significantly enhances the strength of the magneto-ionic effect by a factor of 2, while also reducing the time required for hydrogen insertion by a factor of 10. Our results highlight a route towards faster switching speeds in magneto-ionic devices, which is crucial for future magnetic memory applications.

[1] M. Bischoff et al., Adv. Funct. Mater., **34**, 2405323 (2024)

MA 31.12 Wed 17:00 P1

Investigating Micromagnetic Structures in Dy-Fe Ferrimagnetic Thin Films — •Pranati Parui[1], Tamer Karaman[1], Felix Büttner[1,2], and Manfred Albrecht[1] — [1]University of Augsburg, Augsburg, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany

Ferrimagnetic thin films present a unique platform for studying emergent spin textures and magnetic phenomena due to the interplay between the transition-metal and rare-earth sublattices. Here, we investigate ferrimagnetic Dy-Fe alloy thin films, which exhibit a broad spectrum of magnetic properties that are highly sensitive to composition and temperature. Despite their potential, a systematic investigation of Dy-Fe thin films remains unexplored. This work focuses on the sputter deposition of thin films with varying compositions and employs comprehensive characterization techniques, including SQUID magnetometry, magneto-optical Kerr effect (MOKE) measurements, magnetic force microscopy (MFM), and Lorentz transmission electron microscopy (LTEM), to unravel their micromagnetic structures, domain patterns, and domain wall chirality.

MA 31.13 Wed 17:00 P1

Detecting correlation between surface and interface magnetism of Mn/Fe thin film heterostructures on the atomic scale — •Toshio Miyamachi[1,2], Shuhei Nakashima[1], Yasumasa Takagi[3], Toshiohiko Yokoyama[3], and Fumio Komori[1] — [1]ISSP, The University of Tokyo, Japan — [2]IMaSS, Nagoya University, Japan — [3]Institute for Molecular Science, Japan

The magnetic coupling between ferromagnetic (FM) and antiferromagnetic (AFM) layers has been the focus of interest for magnetic multilayer devices. The fundamental magnetic properties of FM/AFM magnetic multilayers, e.g., magnetic moment, magnetic anisotropy rely much on their interfacial structural and electronic properties. In this work, we investigated structural, electronic and magnetic properties of AFM/FM Mn/Fe thin film heterostructures grown on Cu(001) by spin-polarized scanning tunneling microscopy (Sp-STM) and x-ray absorption spectroscopy/x-ray magnetic circular dichroism (XAS/XMCD) [1]. With the help of surface sensitivity of SP-STM and element specificity of XAS/XMCD, electronic and magnetic properties of surface Mn and interface Fe layers were separately investigated. Sp-STM measurements revealed a new type of surface magnetic structures of Mn layers, which could be interpreted in term of the magnetic coupling with underlying Fe layers.

[1] S. Nakashima et al., Adv. Funct. Mater. 29, 1804594 (2019).

MA 31.14 Wed 17:00 P1

Integration of a dual broadband characterization setup for time-resolved magneto-optical spectroscopy — •Richard Leven, Sophie Bork, David Gutnikov, Umut Parlak, and Mirko Cinchetti — Department of Physics, TU Dortmund, 44227 Dortmund, Germany

We present a recently developed setup for broadband ultrafast magneto-optical pump-probe spectroscopy, optimized for operation at low temperatures and high magnetic fields. The setup utilizes a broadband supercontinuum (white light) probe beam, spanning wavelengths from the near UV to the near IR region. Two independent CMOS detector arrays enable simultaneous data acquisition across all available wavelengths, providing comprehensive insights into transient reflectivity ($\Delta R/R$) and polarization rotation ($\Delta\theta$) measurements in a single experiment. The system operates at variable repetition rates, ranging from <10 kHz to ∼100 Hz, combining the precision of a femtosecond laser source with high sensitivity for low-light conditions. To validate the setup, we conduct experiments on the semiconducting antiferromagnet CrSBr, ensuring the spectrum encompasses the material's bandgap and exciton excitation energies. This poster will detail the technical specifications of the setup, its characterization results, and its performance benchmarks, highlighting its potential for studying ultrafast dynamics in a variety of magnetically ordered systems.

MA 31.15 Wed 17:00 P1

Element-resolved study of antiferromagnetic/ferromagnetic magnetization dynamics in epitaxial CoO/Fe bilayer — •Chowdhury Shadman Awsaf[1], Sangeeta Thakur[1], Markus Weissenhofer[2], Jendrik Gördes[1], Marcel Walter[1], Niko Pontius[3], Christian Schüssler-Langeheine[3], Peter Oppeneer[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin — [2]Department of Physics and Astronomy, Uppsala University — [3]Helmholtz-Zentrum Berlin für Materialien und Energie

We examine the transient AFM spin structure in an epitaxial Fe/CoO bilayer on an Ag(001) single-crystal substrate after excitation by 60 fs laser pulses of 800 and 400 nm wavelength, below and above the CoO band gap, respectively, by evaluating the time-resolved x-ray magnetic linear dichroism in reflectivity at the Co L2 edge. The findings are compared to time-resolved x-ray magnetic circular dichroism measurements at the Fe L3 edge. Both layers exhibit a fast drop in magnetic order within 300 fs. Simulating an atomistic two-temperature model, coupled with the stochastic Landau Lifshitz-Gilbert equation for the spin degrees of freedom, indicates a direct energy transfer from hot Fe electrons to CoO spins in the case of 800 nm excitation. For demagnetization at 400 nm pump, above-band-gap excitation in CoO has to be assumed in the simulation to reproduce the experimental result [1].

[1] C. S. Awsaf et al., arXiv:2408.14360.

MA 31.16 Wed 17:00 P1

Laser-induced magnetostriction in Gd, Tb and Dy probed by UXRD — •Florian Baltrusch[1], Alexander von Reppert[1], Steffen P. Zeuschner[1], Maximilian Mattern[1], Matthias Rössle[2], Florin Boariu[2], Karine Dumesnil[3], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut Jean Lamour, Universite Lorraine, Nancy, France

In ultrafast X-ray experiments, we compare the laser-induced magnetostriction in Gd, Tb and Dy upon femtosecond laser excitation at temperatures above and below the magnetic ordering temperatures. These rare earths exhibit giant spontaneous magnetostriction and consequently negative thermal expansion (NTE). The coupling between magnetic order and the lattice below the Curie temperature leads to a competition between the expansive stresses from electrons and phonons and the contractive stress due to magnetic order. Thus, upon femtosecond laser excitation, the ultrafast dynamics show a variety of interesting results, such as transforming a typical bipolar strain wave into a unipolar pulse. By comparing equilibrium thermal expansion and heat capacities, we separate electronic, phononic, and magnetic stress contributions using an extended Grüneisen model based on energy densities in each of the three subsystems. This enables fitting ultrafast strain dynamics and identifying subsystem coupling constants.

MA 31.17 Wed 17:00 P1

Towards ultrafast time-resolved SHG imaging of ferroic materials — •Andrin Caviezel, Gerrit Horstmann, Thomas Lottermoser, and Manfred Fiebig — Department of Materials, ETH Zurich, Zurich, Switzerland

Ferroic materials enable the storage and manipulation of information within their domain structures, a fundamental property underpinning their technological potential. Second-harmonic generation (SHG) imaging is a well-established method for probing ferroic domain patterns at equilibrium, while optical excitation with femtosecond laser pulses holds promise for achieving ultrafast domain switching. However, studying the non-equilibrium dynamics of ferroic domains demands an imaging technique that offers both high temporal and spatial resolution. In this work, we present an ultrafast time-resolved SHG imaging setup designed specifically to investigate non-equilibrium dynamics in ferroic materials. By utilizing the high pulse energies of an amplified laser system, our setup enables direct wide-field imaging of ferroic structures. Additionally, the ability to tune the laser wavelength and employ sequences of pump pulses provides precise control over optical excitation conditions. This approach allows us to study ultrafast processes both in bulk ferroics with microscopic domain structures and micrometer-sized flakes of van der Waals ferroics under cryogenic conditions, advancing our understanding of their dynamic behavior.

MA 31.18 Wed 17:00 P1

Influence of defects on the ultrafast orbital Hall effect in metallic nanoribbons — •Theresa Albrecht, Franziska Ziolkowski, Oliver Busch, Börge Göbel, Ingrid Mertig, and Jürgen Henk — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

The time-dependent orbital Hall effect, which is generated by a femtosecond laser pulse, called the ultrafast orbital Hall effect (UOHE) is investigated. We present the influence of different types of defects on the UOHE in a Cu nanoribbon. The laser-driven electron dynamics is numerically calculated by our theoretical framework Evolve based on a real-space tight-binding approach for finite systems and the solution of the von Neumann equation for the calculation of the occupation numbers [1]. As a result we discuss charge redistribution and charge currents as well as orbital angular momenta and their currents with atomic resolution in the time domain. The role of defects is analysed quantitatively which is particularly important to compare with experiments.

[1] O. Busch *et al.*, Physical Review Research **6**, 013208 (2024)

MA 31.19 Wed 17:00 P1

Ultrafast magneto-elastic phenomena in highly magnetostrictive materials with systematic variation of anisotropy — •Constantin Walz[1], Fried Weber[1], Karine Dumesnil[2], Alexander von Reppert[1], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Germany — [2]Institut Jean Lamour, Université Lorraine, Nancy, France — [3]Helmholtz-Zentrum Berlin, Germany

Highly magnetostrictive Rare Earth-Iron compounds ($REFe_2$ with RE = Tb, Dy, $Tb_{0.3}Dy_{0.7}$) are well known for their giant (inverse) magnetostriction, with more than 10^{-3} lattice constant change when applying a magnetic field. Because of that they are widely used as ultrasonic transducers in the MHz regime. Their laser-induced magnetization dynamics are less explored, though they have potential as field-tunable magneto-acoustic transducers in the GHz regime or even for strain driven magnetization switching. Here we compare polar transient magneto-optical Kerr effect (trMOKE) data on three (110)-oriented $REFe_2$. The rare-earth ion influences the cubic magnetocrystalline anisotropy energy, leading to nontrivial demagnetization and precession responses with opposing signs for Dy and Tb. We discuss nonresonant strain-driven magnetization dynamics that follow the lattice deformation with a delay. Glass-capped $TbFe_2$ films help to disentangle signal contributions from unipolar strain pulses, quasi-static strain and spin disorder.

MA 31.20 Wed 17:00 P1

Controlling Spin periodicity in a Helical Heisenberg Antiferromagnet — •Hyein Jung[1,2], Abeer Arora[2], Deeksha Gupta[3], Franziska Walther[4], Kristin Kliemt[4], Victoria C. A. Taylor[2], Túlio de Castro[2], Hanqian Lu[1,2], Christian Schüssler-Langeheine[3], Niko Pontius[3], Urs Staub[5], Cornelius Krellner[4], Laurenz Rettig[2], Ralph Ernstorfer[1,2], and Yoav W. Windsor[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [4]Goethe-Universität Frankfurt, Frankfurt, Germany — [5]Paul Scherrer Institut, Villigen, Switzerland

Manipulating antiferromagnetic spin structures is a promising route to new spintronics functionality. This is particularly desirable on ultrafast time scales due to the growing demands for device speeds. Here we investigate the chiral antiferromagnet EuCo2P2 using resonant X-ray diffraction and manipulate the periodicity of its spins under three distinct conditions: (a) femtosecond laser pulse excitation, (b) applied magnetic fields, and (c) heating. These represent fundamentally distinct microscopic routes for manipulation, and their combination can provide an essential basis for achieving precise control of antiferromagnetic spin structures.

MA 31.21 Wed 17:00 P1

Ultrafast demagnetization via 4f-multiplet excitations in Terbium investigated by tr-ARPES — •Timo Dully, Gaurav Kshetry, Xinwei Zheng, Christian Strüber, and Martin Weinelt — Freie Universität Berlin

The magnetic properties of rare earth metals are governed by the localized electrons in the partially filled 4f electron shell and the interaction with the itinerant 3d electrons. Spin polarization of the 4f electrons decreases much faster in Terbium than in Gadolinium [1]. This has been attributed to enhanced coupling to the lattice caused by the anisotropic shape of the electronic wavefunction in Terbium.

However, recent XMCD and RIXS experiments demonstrate an additional excitation pathway that is involved in drastically increasing the response of the magnetic system to optical excitation [2]. Scattering of optically excited 5d electrons with the 4f-subsystem allows for an efficient excitation of the 4f-multiplet.

In our time- and angle-resolved photoemission spectroscopy (tr-ARPES) setup using a hemispherical energy analyzer we measure the demagnetization of Tb as a function of time and fluence. We observe transient changes to the 4f photoemssion signal indicating a substantial excitation of the 4f-multiplet by energy transfer from the 5d valence electrons.

[1] B. Frietsch et al. Sci. Adv. 6(2020) eabb1601
[2] Nele Thielemann-Kühn et al., Sci. Adv. 10 (2024) eadk9522

MA 31.22 Wed 17:00 P1

Probing magnetic dimensional crossover in CrSiTe3 through picosecond strain pulses — •Anjan Kumar Naralapura Manohara[1,2], Soumya Mukherjee[2], Abhirup Mukherjee[2], Ajinkya Punjal[3], Shubham Purwar[4], Thirupathaiah Setti[4], Shriganesh Prabhu[3], Siddhartha Lal[2], and Natarajan Kamaraju[2] — [1]Institute of Solid State and Materials Physics, TUD Dresden University of Technology, Dresden, Germany, 01069 . — [2]Department of Physical Sciences, Indian Institute of Science Education and research, Kolkata, West Bengal, India, 741246. — [3]Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental research, Mumbai, Maharashtra, India, 400005. — [4]Department of Condensed Matter and Materials Physics, S. N. Bose National Centre for Basic Sciences, Kolkata, West Bengal, India, 700 106.

Two-dimensional van der Waals materials provide a unique platform to investigate the evolution of magnetic order from short-range 2D intraplanar to long-range 3D interplanar configurations. Employing non-degenerate pump-probe spectroscopy, we have generated and detected picosecond acoustic strain pulses in CrSiTe3. By analysing the distinct signatures of these pulses, we have elucidated a multi-stage pathway for the magnetic dimensional crossover. Furthermore, our study reveals novel insights into the intricate interplay between spin dynamics and lattice vibrations, as manifested in both picosecond strain pulses and ultrafast carrier dynamics.

MA 31.23 Wed 17:00 P1

Low-temperature XPEEM to study functional properties of magnetic 2D materials — •Shubhada Patil[1], Alevtina Smekhova[2], and Florian Kronast[3] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin, Germany

Two-dimensional (2D) magnetic van der Waals materials are particularly promising for electronic and spintronic devices. They exhibit novel electronic and magnetic properties that are ideally suited for investigation with surface-sensitive X-ray photoemission electron microscopy (XMCD-PEEM). In this poster, the experimental capabilities of the low-temperature PEEM facility at BESSY II are presented, including the possibility to study responses to optical excitations of a femtosecend laser system.

The results presented will focus on investigations of the magnetic properties of 2D heterostructures prepared by mechanical exfoliation of FexGeTe2 crystals (x=3, 4 or 5) with a thickness of up to a few monolayers on gold-coated Si/SiO2 substrates with h-BN capping layer in an inert atmosphere. Element-specific low-temperature imaging in XPEEM with a special sample environment is used to identify the magnetic domain configurations and their dynamic response to optical excitation with fs laser pulses.

MA 31.24 Wed 17:00 P1

Magnon-phonon scattering on ultrafast timescales — •Nabil Makadir, Kai Leckron, and Hans Christian Schneider — Physics Dept, University of Kaiserslautern-Landau (RPTU), Kaiserslautern, Germany

In the ultrafast demagnetization of ferromagnets, electron-magnon scattering likely plays an important role. Recently it has been shown in the framework of a two-band Stoner model (arXiv:2304.14978) that electron-magnon scattering processes lead to the creation of non-equilibrium magnons at large wave vectors on ultrafast time scales. In this contribution, we investigate how a large density of high-q magnons, as it is created during the demagnetization process, relaxes due to magnon-phonon and magnon-electron interactions. Treating phonons as bosons, we solve the dynamical equations for the magnon and phonon distributions including the relevant interactions at the level of Boltzmann scattering integrals. From the numerical results, we draw conclusions for the remagnetization process.

MA 31.25 Wed 17:00 P1

Ultrafast spin flop in Fe/Gd bilayers — Dominic Lawrenz[1], Tim Amrhein[1], Jonathan Weber[1], Wibke Bronsch[1], Niko Pontius[2], Christian Schüssler-Langeheine[2], Nele Thielemann-Kühn[1], and •Martin Weinelt[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin, Germany

Using time-resolved X-ray magnetic circular dichroism in reflection (XMCD-R) at the femtoslicing facility of BESSY II (Helmholtz-Zentrum Berlin) we studied ultrafast magnetization dynamics in an Fe(5 nm)/Gd(11 nm) bilayer on W(110). Structural and magnetic depth profiles of the bilayer were characterized by static $\Theta/2\Theta$ XMCD-R scans. The magnetization $\vec{M}$ lies in-plane with antiparallel alignment of $\vec{M}_{Fe}$ and $\vec{M}_{Gd}$ at the Fe/Gd interface. At 300 K, Gd is magnetized only at the interface. Upon optical excitation Gd demagnetizes within 2 ps reaching a transient ferromagnetic state for ~ 20 ps, comparable to simulations for Co/Gd in [1]. Close to the compensation temperature of 235 K, $\vec{M}_{Fe} = -\vec{M}_{Gd}$ are oriented nearly perpendicular to the external field and twisted into the field direction with increasing distance to the interface. Upon optical excitation we observe a transient spin flop by 6° of the Gd magnetization within 300 fs. This is attributed to spin-transfer torque caused by ultrafast spin currents [2] and may hint to spin vacuum switching [3].

[1] M. Beens et al., Phys. Rev. B **100**, 220409(R) (2019).
[2] B. Liu, H. Xiao, M. Weinelt, Sci. Adv. **9**: eade0286 (2023).
[3] E. I. Harris-Lee et al., Sci. Adv. **10**: eado6390 (2024).

MA 31.26 Wed 17:00 P1

Setting up current-induced spin-wave Doppler shift experiments — •Linda Nesterov, Julian Strassburger, Johannes Demir, Karsten Rott, and Timo Kuschel — Universität Bielefeld, Germany

The coupling of coherent spin waves with incoherent spin transport, such as spin-polarized electrons, results in the transfer of angular momentum via spin-transfer torque, enabling the so-called spin-wave Doppler shift [1]. Our research aims to deepen the understanding of this fundamental process, which plays a significant role in the development of next-generation memory devices and other spintronic applications. Propagating spin-wave spectroscopy is used to detect a possible Doppler shift in spin waves generated by charge currents in a 20 nm thick $Ni_{81}Fe_{19}$ strip. The experiments are conducted using a vector network analyzer with both in-plane and out-of-plane magnetic fields applied perpendicular to the direction of the propagating spin wave, which is excited with the use of a coplanar waveguide design. In contrast to published works [1,2], this study uses Ta_2O_5 as an insulating material, chosen for its high permittivity, leading to a different impedance matching within the system.

[1] V. Vlaminck, M. Bailleul, Science 322, 410 (2008)
[2] J. Lucassen et al., Appl. Phys. Lett. 115, 012403 (2019)

MA 31.27 Wed 17:00 P1

Angle-dependent pumping of magnon Bose-Einstein condensates — •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 generation and behavior of magnon Bose-Einstein condensates (BEC) in yttrium-iron-garnet films. To create a magnon BEC, the magnon gas must be populated above the thermal level by external injection of magnons. Conventionally, this is done by parallel parametric pumping, where magnons are injected into spin-wave modes at half the pumping frequency. This work aims to optimize the pumping configuration by changing the direction of the microwave pumping field relative to the external magnetic field. This concept of oblique pumping promises higher efficiency and easier manipulation of the magnon BEC. The measurements are performed using a vector magnet for the rotation of the external magnetic field and Brillouin light scattering spectroscopy as an optical detection method for magnons. First results promise lower thresholds for the pumping power and thus easier excitation of magnons leading to a magnon BEC. This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-TRR 173/3-268565370 Spin+X (Project B04)

MA 31.28 Wed 17:00 P1

Towards Aharonov–Casher effect based nonreciprocal electrical control of the magnon phase in a perpendicularly magnetised YIG film — •Gabriel Schwöbel[1], Alexander A. Serga[1], Vitaliy I. Vasyuchka[1], Rostyslav O. Serha[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU, 67663 Kaiserslautern — [2]Faculty of Physics, University of Vienna, 1090 Vienna

Modulation of phase and amplitude of spin waves plays a crucial role in the realization of ultra-low power magnon-based computing. Therefore, we study the magnon phase change, induced by an applied electric field, in yttrium iron garnet (YIG), which has favourable magnetic properties such as a very low spin wave damping.

Recent studies [1] performed in in-plane magnetized single crystal YIG films have allowed us to evaluate different contributions to this phase change and to provide experimental evidence for the theoretically predicted magnonic Aharonov–Casher effect. This effect describes the accumulation of a geometric phase when a magnon passes through an electric field. In our new setup, which provides a more homogeneous and stable magnetic field, we investigate the non-reciprocal effects of magnon phase accumulation when a tangential electric field is applied to an out-of-plane magnetized YIG film.

[1] R.O. Serha et al., *Towards an experimental proof of the magnonic Aharonov–Casher effect*, Phys.Rev. B **108**, L220404 (2023)

MA 31.29 Wed 17:00 P1

Towards magnetically controlled phononic crystals — •Philipp Knaus, Maximilian Alexander Thiel, Kaya Gauch, and Mathias Weiler — Fachbereich Physik and Landesforschungszentrum Optimas, RPTU Kaiserslautern, Germany

Phononic crystals (PnCs) are materials with periodic modulations in their elastic properties that allow precise tuning of the phonon dispersion relation, enabling control of phonon propagation, including bandgaps, waveguiding and confinement. Recent advances have focused on 2D PnCs, which support innovative applications such as nanoscale information processing, optomechanical systems and thermal management [1]. This work represents a first step towards magnetically controlled PnCs based on surface acoustic waves, where the phononic properties of the material can be tuned. We study a magnetically controlled PnC based on Lithium Niobate $LiNbO_3$/CoFeB heterostructure. We characterize our prototype by electrical transmission measurements using a vector network analizer and optical measurements based on Brillouin Light Scattering and the time-resolved magneto-optic Kerr effect. Based on our results, we discuss potential applications and device optimization.

[1] M. Sledzinska et. al, Adv. Funct. Mater. 8, 30 (2020)

MA 31.30 Wed 17:00 P1

Spin Hall driven spin-wave emission in Ga:YIG/Pt heterostructures — •Moritz Bechberger[1], David Breitbach[1], Björn Heinz[1], Carsten Dubs[2], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

The development of a DC driven and scalable spin-wave source that exhibits a self-adaptive frequency is desirable. In particular, spin currents can be used for these spin-wave sources, but instead of radiating energy in the form of propagating spin waves, localized oscillations occur in most systems due to the underlying negative nonlinear frequency shift. Here, a heterostructure consisting of an yttrium iron garnet thin film substituted with gallium atoms (Ga:YIG), which exhibits a perpendicular magnetic anisotropy, and a thin layer of platinum is employed. The heterostructure allows studies in the positive nonlinear frequency shift regime for in-plane magnetization. A spin current is locally injected into the Ga:YIG film via the spin Hall effect by applying a direct current to the platinum pad. This allows for the study of the spin-wave emission into the adjacent Ga:YIG waveguide. The emission of spin waves was found to be partially decoupled from the auto-oscillation and is restricted to a narrow frequency and wave-vector range. This work provides a proof-of-concept and the fundamental basis for the development of spin-wave emitters utilizing this mechanism. This research is funded by the DFG - Project No. 271741898, TRR 173-268565370 (B01), and the ERC Grant No. 101042439 CoSpiN.

MA 31.31 Wed 17:00 P1

Controlling the Bi/Fe ratio in bismuth iron garnet thin films deposited by confocal magnetron sputtering for enhanced Faraday rotation — Gajendra L. Mulay[1,2], •Shraddha Choudhary[3], Bhagyashree A. Chalke[1], Rudheer D. Bapat[1], Jayesh B. Parmar[1], Manish B. Ghag[1], Vilas J. Mhatre[1], Shriganesh Prabhu[1], Ashwin A. Tulapurkar[2], and Venu Gopal Achanta[1,4] — [1]TIFR, Mumbai, 400005, India. — [2]IIT Bombay, Mumbai, 400076, India. — [3]Institute of Physics, University of Münster, Wilhelm-Klemm-Str. 10, Münster, 48149, Germany. — [4]On lien at CSIR-NPL, New Delhi, 110012, India.

Among all known garnet films bismuth-iron-garnet (BIG;$Bi_3Fe_5O_{12}$) films not only demonstrate the highest Faraday rotation in visible light but also exhibit minimal optical losses. We have successfully deposited high-quality BIG epitaxial thin films on single-crystal gadolinium-gallium-garnet (GGG;$Gd_3Ga_5O_{12}$) (111) substrates via Radio frequency confocal sputtering, utilizing separate bismuth and iron oxide sputtering targets and optimized thermal treatments. The Bi/Fe ratio in the deposited BIG thin films can be varied by controlling the sputter process parameters. These deposited thin films exhibit homogeneity and surface root mean square roughness of less than 2 nm. The epitaxial film quality is confirmed by X-ray diffraction and Transmission electron microscopy. Moreover, the films demonstrate low optical loss and a magneto-optical Faraday rotation as high as $-34^o \pm 1^o/\mu$m at a wavelength of 535 nm for a BIG thin film with a Bi/Fe ratio of 0.7 and an annealing temperature of 510^oC.

MA 31.32 Wed 17:00 P1

Ultrafast dynamics in photoexcited antiferromagnets — •Katja Sophia Moos[1], Yun Yen[2], Arnau C. Romaguera[3], Hiroki Ueda[3], and Michael Schüler[1,2] — [1]Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland — [2]PSI Center for Scientific Computing, Theory and Data, 5232 Villigen PSI, Switzerland — [3]PSI Center for Photon Science, 5232 Villigen PSI, Switzerland

State-of-the-art time-resolved probes provide unprecedented access to the dynamics of interacting quasiparticles in solids on their natural time scales. Although a significant body of work exists on the dynamics of electrons and phonons, much less is known about the ultrafast response of magnetic moments. Here, we study pump-induced out-of-equilibrium magnetism in the Mott insulator CuO, combining measurements of resonant magnetic X-ray scattering with quantum-kinetic simulations. In particular, the diffuse scattering reveals time-dependent magnetic correlations, which we interpret in terms of interacting magnons. For quantitative insights, we solve the time-dependent quantum Boltzmann equation to study magnon-magnon scattering. The calculations are consistent with experimental observations and provide a detailed picture of magnetic dynamics in terms of non-thermal magnons and their subsequent thermalization.

MA 31.33 Wed 17:00 P1

Investigating Spin Cherenkov Radiation in Magnetic Materials Using MuMax3 Simulations — •Kawa Noman, Matthias Schweizer, Vitaliy Vasyuchka, and Mathias Weiler — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Spin Cherenkov Radiation (SCE) is a groundbreaking mechanism that enables the emission of spin waves (magnons) in ferromagnetic materials when an external perturbation surpasses the minimum phase velocity of these spin waves. In this study, we employ MuMax3 micromagnetic simulations to investigate SCE induced by high-amplitude Surface Acoustic Waves (SAWs) in Yttrium Iron Garnet (YIG) thin films. Our simulations reveal that SAWs propagating at velocities exceeding the spin wave phase velocity efficiently excite coherent spin wave modes, exhibiting characteristic Cherenkov like conical wavefronts. Through comparative analysis with Cobalt Iron Boron (CoFeB), we affirm the universal nature of SCE across diverse ferromagnetic materials, thereby highlighting its significant potential for advanced applications in magnonic and spintronic devices. This study not only establishes spin Cherenkov Radiation as a fundamental physical phenomenon but also paves the way for innovative technologies that leverage controlled spin wave emission.

MA 31.34 Wed 17:00 P1

Excitation of spin waves via surface acoustic waves in com-

plex magnetic domain structures — •Mohammad Javad Kamali Ashtiani[1], Alexandre Abbass Hamadeh[2], Ephraim Spindler[1], Mathias Weiler[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Center de Nanosciences et de Nanotechnologies, CNRS, Universite Paris-Saclay, 91120, Palaiseau, France

We investigated the interaction of surface acoustic waves (SAWs) with spin waves (SWs) in micrometer-sized cobalt-iron-boron (CoFeB) dots on a piezoelectric –ScAlN– substrate. These dots exhibit particular domain structures leading to complex magnon-phonon coupling. SAWs, generated using interdigital transducers across a broad GHz frequency range, were observed to excite SWs in the CoFeB structures. The dynamics were characterized using micro-focused Brillouin light scattering (*BLS) spectroscopy, allowing direct detection of SAW and SW excitations. Nitrogen-vacancy magnetometry provided high-resolution insights into the magnetic domain arrangement. Also, Mumax3 simulations confirmed the complex domain textures. The response of SWs at specific resonance magnetic fields was observed and shifted across different frequencies. Our findings highlight the potential of hybrid phonon-magnon systems for tunable magnonic devices, advancing wave-based information processing technologies. This research was supported by DFG under TRR 173/3 - 268565370 Spin+X (Project B01).

MA 31.35 Wed 17:00 P1

All-Magnonic Frequency Multiplication in Ferromagnetic Microstructures — •Alexandra Schrader[1], Chris Körner[1], Rouven Dreyer[1], Niklas Liebing[2], and Georg Woltersdorf[1] — [1]Martin-Luther-Universität Halle-Wittenberg — [2]Fraunhofer Institute for Electronic Nano Systems ENAS, Chemnitz

We have observed all-magnetic frequency multiplication and a six-octave frequency comb in polycrystalline NiFe thin films [1]. At low bias fields, magnetic ripples cause local magnetization tilting, and MHz-range excitation induces rapid switching and high-harmonic spin wave emission. To enable practical applications, it is essential to miniaturize active components and optimize the frequency multiplication efficiency, aiming to generate GHz-range spin waves using MHz rf excitation in minimal-sized elements.

Recently, frequency multiplication has also been observed in extended CoFeB layers [2]. This motivates us to investigate the effect in both thin films as well as microstructures of CoFeB. Using micromagnetic simulations, we analyze how various parameters - such as saturation magnetization, anisotropy, static bias field and the shape, size and thickness of micrometer-sized CoFeB elements - influence generation efficiency. These numerical results are then compared to experimental measurements performed via NV magnetometry and SNS-MOKE techniques on actual samples.

[1] Koerner et al., Science 375, 6585 (2022)
[2] Wu et al., npj Spintronics 2, 30 (2024)

MA 31.36 Wed 17:00 P1

Magnetoacoustic coupling in Yttrium Iron Garnet / Aluminium Scandium Nitride heterostructures — •Kevin Künstle[1], Kaya Gauch[1], Yannik Kunz[1], Agne Žukauskaite[2,3], Stephan Barth[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Fraunhofer Institute for Electron Beam and Plasma Technology FEP, 01277 Dresden, Germany — [3]Institute of Solid State Electronics, Technische Universität Dresden, 01062 Dresden, Germany

The magnetoelastic coupling between surface acoustic waves (SAWs) and spin waves (SWs) has garnered significant attention in recent years. Magnetoelastic excitation of SWs is particularly appealing in ferrimagnets with low magnetic damping, such as yttrium iron garnet (YIG). To enable the electrical excitation of SAWs, a piezoelectric layer is required. We have demonstrated that ZnO is a suitable choice [1]. In this study, a novel heterostructure comprising a YIG/GGG bilayer covered by a piezoelectric AlScN thin film is investigated to explore this coupling. The interaction of SAW and SW is characterized using micro-focused Brillouin light scattering (BLS) spectroscopy and vector network analyzer (VNA) measurements. Additionally, the observed magnetoelastic coupling is benchmarked against the coupling in the more established ZnO/YIG/GGG heterostructure.

[1] Ryburn et al., arXiv 2403.030006 (2024)

MA 31.37 Wed 17:00 P1

Efficient all-magnonic frequency multiplication in nanoscale devices — •Chris Körner[1], Anna Kiefel[1], Rouven Dreyer[1], Alexandra Schrader[1], Niklas Liebing[2], and Georg Woltersdorf[1] — [1]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Von Danckelmann Platz 3, 06120 Halle (Saale) — [2]Fraunhofer-Institut für Elektronische Nanosysteme ENAS, Technologie-Campus, 3 09126 Chemnitz

We recently have observed all-magnonic frequency multiplication and the generation of a 6-octave spanning frequency comb within an extended polycrystalline NiFe layer [1]. At low bias fields the magnetization locally tilts due to a magnetic ripple effect in the film. Driving the magnetization with frequencies far below ferromagnetic resonance, i.e. in the MHz range, causes rapid synchronous switching and leads to high harmonic spin wave emission. To make use of this effect in an actual device it is necessary to shrink the dimensions of the active components and to enhance the efficiency of the frequency multiplication process. The aim is to generate spin waves in the range of up to 10 GHz most efficiently in elements as small as possible, just from r.f. excitation with MHz frequencies. We employ micromagnetic simulations to investigate how the generation efficiency is influenced by external parameters, such as bias field and the shape, size, and thickness of micrometer sized NiFe elements. We find that the comb generation process can still be efficient even if we scale down the elements to just a few microns and compare these results to NV-center and SNS-MOKE measurements. [1] Koerner et al. Science, 375 (6585) 2022.

MA 31.38 Wed 17:00 P1

Realization of Inverse-Design Magnonic Logic Gates — •Fabian Majcen[1,2], Noura Zenbaa[1,2], Claas Abert[1,3], Florian Bruckner[1,3], Norbert Mauser[3,4], Thomas Schrefl[3,5], Qi Wang[6], Dieter Süss[1,3], and Andrii Chumak[1,3] — [1]University of Vienna, Faculty of Physics, Vienna 1090, Austria — [2]University of Vienna, Vienna Doctoral School in Physics, Vienna 1090, Austria — [3]Research Platform MMM "Mathematics-Magnetism-Materials", University of Vienna, Vienna 1090, Austria — [4]Faculty of Mathematics, University of Vienna, Vienna 1090, Austria — [5]Center for Modelling and Simulation, Donau-Universität Krems, Wiener Neustadt, 2700, Austria. — [6]School of Physics, Hubei Key Laboratory of Gravitation and Quantum Physics

The field of Magnonics, which utilizes magnons, the quanta of spin waves, for energy-efficient data processing, has made significant advancements through the application of inverse design. A universal magnonics processor has been developed, utilizing a 7x7 array of independent current loops to generate local inhomogeneous magnetic fields, thereby scattering spin waves in an Yttrium-Iron-Garnet film to achieve various functionalities. In this system, binary data ('0' and '1') is encoded in the spin-wave amplitude, and by making use of the nonlinearity of spin waves and applying the inverse-design process, logic gates including NOT, OR, NOR, AND, NAND, and a half-adder have been successfully created.

MA 31.39 Wed 17:00 P1

Yttrium iron garnet nanostructures for spin-wave computing — •Jannis Bensmann[1], Ahmad El Kadri[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, 69120 Heidelberg, Germany

The ever-increasing demand for computing power, particularly driven by the recent advances in the field of artificial intelligence, has triggered research into novel system architectures to improve the performance of current computing technology. Here, spintronics appears as a promising candidate, as spin waves are energy-efficient, broadband (up to THz), and can have wavelengths down to the nanometer scale. In order to realize hardware-based spin-wave computing, we employ nanofabrication techniques to create devices from 100-nm-thick films of yttrium iron garnet (YIG), a material well known for its exceptional low-damping. We evaluate the performance of individual building blocks using optical measurements such as Brillouin light scattering, which provides detailed insights into the spin-wave propagation.

MA 31.40 Wed 17:00 P1

Manipulation of spin waves in YIG/FM heterostructures — •Julien Schäfer, Akira Lentfert, Björn Heinz, and Philipp Pirro — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

The concept of using spin waves as data carriers is a promising alternative to existing communication standards with the potential for energy efficient data transfer. In magnonics, communication building blocks, such as time-delay lines for phase modulation, can be realized by exploiting the magnetic field-dependent spin-wave group velocities in e.g. yttrium-iron-garnet (YIG). In particular, the spin wave propagation in Damon-Eshbach geometry can be modified by the deposition of an additional ferromagnetic layer, leading to a strong frequency nonreciprocity induced by dipolar interaction. Here, we report an on-chip configurable magnonic frequency filter/phase shifter device consisting of a YIG transmission line with iron stripes deposited on top. These stripes act as Fabry-Pérot (FP) resonators due to the spin-wave reflections at the boundaries. Destructively interfering spin waves are filtered by such a resonator, while the transmitted spin waves accumulate an additional phase due to the altered dispersion relation in the bilayer region. We present micromagnetic studies investigating the tunability of these FP resonators by means of external parameters such as local magnetic fields and the stripe magnetization configuration. This research is funded by the European Union within HORIZON-CL4-2021-DIGITAL-EMERGING-01 (No.101070536, MandMEMS).

MA 31.41 Wed 17:00 P1

Mapping of the Morin Transition in alpha-Fe2O3 using Surface Acoustic Waves — •Katharina Lasinger[1,2], Florian Kraft[1], Yannik Kunz[1], Kevin Künstle[1], Finlay Ryburn[2], John F. Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Clarendon Laboratory, Department of Physics, University of Oxford, United Kingdom

Antiferromagnets (AFMs) hold great potential for applications due to their insensitivity to external magnetic fields, the absence of associated stray fields and and their ability to host fast spin dynamical phenomena [1,2]. While AFMs interact only weakly with external magnetic fields, their magnetic order couples to elastic deformation. We investigate the manipulation of AFMs using magnetoelasticity and demonstrate both the possibility to probe changes in the static magnetization as well as map out the Morin transition of alpha-Fe2O3 through concurrent modification of its elastic properties. To achieve this, surface acoustic waves (SAWs) are launched in an alpha-Fe2O3 | ZnO heterostructure while magnetic field sweeps are performed. We observe significant changes in SAW group velocity and amplitude depending on the angle of the external magnetic field relative to the crystallographic c-axis and the SAW propagation direction. A temperature-dependent study around the Morin transition reveals the critical fields at each temperature required for the antiferromagnetic phase transition to occur.

[1] A. V. Chumak, et al., Nature Physics 11, 453 (2015).
[2] S. M. Rezende, et al., J. Appl. Phys. 126, 151101 (2019).

MA 31.42 Wed 17:00 P1

Interlayer coupling in Co/Pd multilayers with perpendicular magnetic anisotropy — •Raphael Kohlstedt[1,2], Rico Ehler[1,2], Peter Heinig[1,2], and Olav Hellwig[1,2,3] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Research Center MAIN, D-09126 Chemnitz, Germany — [3]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany

Antiferromagnetically (AF) coupled perpendicular magnetic anisotropy (PMA) multilayers (MLs) are widely utilized in magnetic devices. In Co/Pd MLs with PMA, the coupling is implemented via non-magnetic spacer layers like Ru or Ir. Using Pd itself as a spacer would be beneficial, since purely-Pd-based systems are promising candidates for applications in magneto-ionics, as demonstrated in recent reports [1-3]. In sputtered Co/Pd/Co trilayers, aging under ambient conditions induces a transient coupling effect, leading to a transition from ferromagnetic to antiferromagnetic coupling [4]. Building onto these experiments, we investigate the coupling behavior in Co/Pd/Co trilayers and Co/Pd MLs separated by a thicker Pd spacer. In our samples, we observe AF coupling as well as distinctly time-dependent effects, differing from those reported previously.

[1] A. E. Kossak et al., Sci. Adv., 9(1), 2023
[2] A. E. Kossak et al., Adv. Funct. Mater., 34(46), 2024
[3] M. Gößler et al., Adv. Funct. Mater., 34(40), 2024
[4] F. S. Wen et al., J. Appl. Phys., 110(4), 2011

MA 31.43 Wed 17:00 P1

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

Magnetic circular dichroism (MCD) effect has a cos (θ) dependence where θ is the angle between light polarization and sample magnetization. This yields direct information about the magnetization direction with respect to the polarization of the synchrotron X-ray beam for both ferromagnetic and antiferromagnetic materials. 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. Extracting quantitative information about absolute values of local magnetic moments is very challenging, because of the complicated structure of photoelectron spectra. For example, the 4eV Co satellite cannot be explained by the solid-state calculations. The satellite obviously exhibits strong dichroism.

The electronic and magnetic properties of CoFe, CoFeB and Co-based Heusler nanolayers were studied using 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.

MA 31.44 Wed 17:00 P1

Kerr Microscopy Studies of Magnetic Domains in proximity-coupled 3d FM-EuO Heterostructures — •Katharina Wehrstein, Seema Seema, Pia Maria Düring, and Martina Müller — FB Physik, Universität Konstanz, 78457 Konstanz

Europium monoxide (EuO) is a promising material for future spintronic applications as it is an insulator with a similar band gap to silicon, is ferromagnetic (FM) up to a Curie temperature (T_c) of 69 K and shows good spin-filter qualities. Since the low T_c is limiting for applications, methods to increase T_c are actively investigated. For this purpose, it is important to understand the magnetic behavior of EuO below, near and above T_c. One possible option to increase T_c is the proximity coupling of EuO with room temperature (RT) FM such as Fe or Co. Here, the temperature- and thickness-dependent magnetization of EuO thin films and 3d FM coupled EuO heterostructures synthesized by molecular beam epitaxy was investigated using magneto-optical Kerr microscopy. Systematic temperature- and thickness-dependent investigations on one hand revealed that the magnetic domain structure in Fe undergoes significant modifications in the presence of EuO, compared to Co. On the other hand, coercivity gets more affected due to the presence of Co than Fe. Such observations could lead to tuning thickness of EuO and overlayer choice in proximity-coupled heterostructures with T_c close to RT for applications.

MA 31.45 Wed 17:00 P1

Phase Modulation of Spin Waves via Surface Acoustic Waves — •Tim Vogel, Björn Heinz, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau

The interaction of spin waves and surface acoustic waves (SAWs) offers promising opportunities for advanced spintronic and magnonic applications. This study investigates the feasibility of using low-frequency SAWs in the MHz range to modulate the phase of high-frequency spin waves in the GHz range. Using micromagnetic simulations with mumax3, we investigate the dynamic coupling mechanisms and conditions necessary for effective phase manipulation of propagating spin waves.

While the primary focus is theoretical, this work also provides a framework for potential experimental validation to elucidate key factors such as coupling efficiency, propagation dynamics and system geometry. These results will contribute to a deeper understanding of magnon-phonon interactions.

We acknowledge funding by the European Union via Horizon Europe project MandMEMS, Grant No. 101070536.

MA 31.46 Wed 17:00 P1

Antiferromagnetic coupling in Co/Au/Co tri-layers — Lokesh Rasabathina[1], Rico Ehrler[1], Markus Gössler[1], Karin Leistner[1], Georgeta Salvan[1,2], and •Olav Hellwig[1,2,3] —

[1]Chemnitz University of Technology, Chemnitz, Germany — [2]Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology,Chemnitz, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Magnetic thin film systems are of great interest for many applications, such as magnetic memory, storage, sensor devices, etc. Specifically synthetic antiferromagnets (SAFs) with perpendicular magnetic anisotropy are of interest in the fabrication of nanomagnetic and spintronic devices[1]. In reference to earlier studies[2], we fabricate thin films consisting of $Au_{seed}/Co_{(1)}/Au_{interlayer}/Co_{(2)}/Au_{cap}$ layer stack using magnetron sputtering in ultra-high vacuum conditions. Varying the $Au_{interlayer}$ thickness the $Co_{(1)}$ and $Co_{(2)}$ layers either reverse separately at different switching fields or jointly at the same switching field. We investigate if the interaction between the two cobalt layers originates from RKKY coupling, orange-peel coupling or through growth induced asymmetry between the two cobalt layers[3]. The Au_{seed} layer thickness also seems to affect the observed reversal behaviour. For our sample characterization, we use different types of magnetometry and magnetic microscopy techniques.

[1] R.A.Duine, et al., Nat. Phys. 14, 217 (2018)
[2] M. Matczak et al., J. Appl. Phys., vol. 114, no. 9 (2013)
[3] V. Grolier et al, Phys. Rev. Lett. 71, 3023 (1993)

MA 31.47 Wed 17:00 P1

Site-selective substitution effects on the magnetic phase diagram of multiferroic $Fe_2Mo_3O_8$ — Lilian Prodan[1], •Dorina Croitori[2], Irina G. Filippova[2], Sergiu Shova[3], Vladimir Tsurkan[1,2], and Istvan Kezsmarki[1] — [1]University of Augsburg — [2]Moldova State University — [3]Romanian Academy

Antiferromagnetic materials hold great promise for the design of ultrafast and energy-efficient spintronic devices. Therefore, understanding the robustness of crystals, their magnetic structures, and their manipulation is of high importance. Here, we report the effect of site-selective substitution of Zn^{2+} for Fe^{2+} ions on the crystal structure, magnetic and thermodynamic properties of the multiferroic $Fe_2Mo_3O_8$. We found the strong preference of Zn to occupy the tetragonal positions for substitution concentrations $\mathbf{0 \geq x \leq 1.3}$. This contrasts the previously reported results for related system $Co_2Mo_3O_8$ [1]. Site-selective substitution affects the magnetic phase diagram of $Fe_2Mo_3O_8$ influencing both the intra and inter-layer exchange interactions. This leads to the stabilization of the FiM phase for $\mathbf{x \geq 0.2}$ and to the decrease of T_C with increasing the Zn content. [1]. L. Prodan, I. Filippova, et al. Phys Rev B 106 (2022) 174421.

MA 32: Spin Transport and Orbitronics, Spin-Hall Effects II (joint session MA/TT)

Time: Wednesday 17:30–19:00 Location: H19

MA 32.1 Wed 17:30 H19

Orbital torques and orbital pumping in two-dimensional rare-earth dichalcogenides — •Mahmoud Zeer[1,2,3], Dongwook Go[3], Mathias Kläui[3,4], Wulf Wulfhekel[5], Stefan Blügel[1], and Yuriy Yuriy Mokrousov[1,3] — [1]Peter Gr *unberg Institute, Forschungszentrum J *ulich, 52425 J *ulich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, German — [3]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [4]Centre for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, 7491 Trondheim, Norway — [5]5Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

The design of spin-orbit torque (SOT) properties in two-dimensional (2D) materials represents a key challenge in modern spintronics. We now explore ferromagnetic Janus H-phase monolayers of 4f-Eu rare-earth dichalcogenides EuSP, EuSSe, and EuSCl using first-principles calculations. Our findings reveal that these compounds exhibit substantial SOT, primarily driven by the colossal current-induced orbital response of Eu f-electrons. Additionally, the resulting orbital torques can generate strong in-plane currents of orbital angular momentum with non-trivial orbital polarization directions. These results establish f-based 2D materials as a highly promising platform for in-plane orbital pumping and SOT applications, positioning f-based 2D materials as a promising platform for next-generation orbitronic and spintronic technologies with 2D materials.

MA 32.2 Wed 17:45 H19

Orbital Topology of Chiral Crystals for Orbitronics — •Ying-Jiun Chen[1], Kenta Hagiwara[1,2], Dongwook Go[3], Xin Liang Tan[1,2], Sergii Grytsiuk[1], Kui-Hon Ou Yang[4], Guo-Jiun Shu[5], Jing Chien[4], Yi-Hsin Shen[4], Xiang-Lin Huang[5], Iulia Cojocariu[1], Vitaliy Feyer[1,2], Minn-Tsong Lin[4,6], Stefan Blügel[1], Claus Michael Schneider[1,2], Yuriy Mokrousov[1,3], and Christian Tusche[1,2] — [1]Forschungszentrum Jülich — [2]University of Duisburg-Essen — [3]Johannes Gutenberg University Mainz — [4]National Taiwan University, Taiwan — [5]National Taipei University of Technology, Taiwan — [6]Academia Sinica, Taiwan

Chirality is ubiquitous in nature and manifests in a wide range of phenomena including chemical reactions, biological processes, and quantum transport of electrons. In quantum materials, the chirality of fermions, given by the relative directions between the electron spin and momentum, is connected to the band topology of electronic states. Here, we show that in structurally chiral materials like CoSi, the orbital angular momentum (OAM) serves as the main driver of a nontrivial band topology in this new class of unconventional topological semimetals, even when spin-orbit coupling is negligible. A nontrivial orbital-momentum locking of multifold chiral fermions in the bulk leads to a pronounced OAM texture of the helicoid Fermi arcs at the surface. Our findings highlight the pivotal role of the orbital degree of freedom for the chirality and topology of electron states, in general, and pave the way towards the application of topological chiral semimetals in orbitronic devices.

MA 32.3 Wed 18:00 H19

Vectorial flow of the Berry curvature and its relation to the transport and band structure — •Jaroslav Hamrle[1,2], Ondřej Stejskal[1], Milan Vrána[2,1], and Martin Veis[2] — [1]Czech Technical University, Prague, Czechia — [2]Charles University, Prague, Czechia

Berry curvature expresses the curvature of the reciprocal space, in a similar manner as magnetic field express curvature of the real space, resulting in a curved transport of electrons in solids. Therefore, Berry curvature is a base of various lossless transport phenomena such as anomalous Hall effect, anomalous Nerst effect, orbital magnetization or electric polarization. Here, in model materials bcc Fe and Fe_3Ga, we demonstrate details of the vectorial flow of the Berry curvature (monopole source, 1-dimensional flow, 2-dimensional flow), and its relations to the band structure, orbital magnetization as well as anomalous Hall and Nerst effects.

[1] O. Stejskal, M. Veis, J. Hamrle, Sci Rep **12**, 97 (2022) [doi: 10.1038/s41598-021-04076-z]

[2] O. Stejskal, M. Veis, J. Hamrle, Phys. Rev. Materials **7**, 084403 (2023) [doi:10.1103/PhysRevMaterials.7.084403]

MA 32.4 Wed 18:15 H19

Finite-temperature transport properties of magnetic/non-magnetic alloys: trends in the longitudinal and in the transverse charge and spin currents — •Alberto Marmodoro[1], Yang Wang[2], Yuqing Lin[3], and Ilja Turek[4] — [1]Institute of Physics (FZU), Czech Academy of Sciences, Prague, Czech Republic — [2]Pittsburgh Supercomputer Center (PSC), Carnegie Mellon University, Pittsburgh, USA — [3]Mellon College of Science, Carnegie Mellon University, Pittsburgh, USA — [4]Institute of Physics of Materials, Czech Academy of Sciences, Brno, Czech Republic

Alloys composed of magnetic and non-magnetic metals exhibit nontrivial transport trends as a function of composition and temperature. The stoichiometry controls not only the Curie point, but also the slope of resistivity vs. temperature. Beside affecting longitudinal currents, this has further implications also for transverse charge and spin currents, i.e. on anomalous Hall effects [1]. We report first-principles results based on density functional theory (DFT), relativistic linear response and Green function methods based on the multiple scattering Korringa-Kohn-Rostoker (KKR) or linear muffin tin orbitals (LMTO) frameworks.

[1] "Large anomalous Hall angle in the Fe(60),Al(40) alloy induced by substitutional atomic disorder" by J.Kudrnovsky et al. PRB 101, 054437 (2020); "Exploiting Spin Fluctuations for Enhanced Pure Spin Current" by P.Wu et al. PRL 128, 227203 (2022); "Critical enhancement of the spin Hall effect by spin fluctuations" by S.Okamoto et al. Quantum Materials 29, 9 (2024).

MA 32.5 Wed 18:30 H19

Impact of the substrate on angular momentum transport between separated ferromagnets — •Fiona Sosa Barth[1,2], Matthias Grammer[1,2], Richard Schlitz[3], Tobias Wimmer[1,2], Janine Gückelhorn[1,2], Luis Flacke[1,2], Sebastian T.B. Goennenwein[3], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], Akashdeep Kamra[5], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, BAdW, Garching, Germany — [2]School of Natural Sciences, TUM, Garching, Germany — [3]Department of Physics, University of Konstanz, Konstanz, Germany — [4]Munich Center for Quantum Science and Technology, München, Germany — [5]RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

Spintronics relies on the transfer of angular momentum between electrons and solid state excitations such as magnons and phonons. In our recent work, we demonstrate angular momentum transfer between two ferromagnetic strips on diamagnetic substrates [1] by converting a DC current at one of the electrodes to a non-equilibrium magnon accumulation. Due to dipolar and potentially phononic coupling, angular momentum is transferred to the magnonic system of the second FM electrode and measured by the inverse processes. In this work, we investigate the substrate influence on the angular momentum transport by comparing our results for SiOx and SiN layers on Si substrates. As a next step, we investigate substrate-supported strips versus freestanding strings to separate phononic contributions from dipolar coupling.

[1] R. Schlitz et al., Phys. Rev. Lett. 132, 256701 (2024)

MA 32.6 Wed 18:45 H19

Orbital Edelstein contribution to the spin-charge conversion in Germanium Telluride — •Sergio Leiva-Montecinos[1], Libor Vojáek[2], Jing Li[2], Mairbeck Chshiev[2], Ingrid Mertig[1], and Annika Johansson[3] — [1]Martin Luther University Halle-Wittenberg, Halle (Saale), Germany — [2]Université. Grenoble Alpes, CEA, CNRS, SPINTEC, Grenoble, France — [3]Max Planck Institute of Microstructure Physics, Halle (Saale), Germany

The Edelstein effect (EE) is a promising mechanism for generating spin and orbital polarization from charge currents in systems without inversion symmetry. In ferroelectric materials, such as Germanium Telluride (GeTe), the combination of bulk Rashba splitting and voltage-controlled ferroelectric polarization provides a pathway for reversible spin-charge interconversion [1, 2].

In this work, we investigate current-induced spin and orbital magnetization in bulk GeTe using Wannier-based tight-binding models derived from DFT calculations and semiclassical Boltzmann theory. Employing the modern theory of orbital magnetization (MTOM), we demonstrate that the orbital Edelstein effect (OEE) entirely dominates its spin counterpart (SEE). This difference is visualized through the spin and orbital textures at the Fermi surfaces, where the orbital moment surpasses the spin moment by one order of magnitude. Moreover, the OEE remains largely unaffected when we suppress the spin-orbit coupling, highlighting its distinct physical origin compared to the SEE.

[1] D. Di Sante *et al.*, Adv. Mater. **25**, 509 (2012).
[2] C. Rinaldi *et al.*, Nano Lett. **18**, 2751 (2018).

MA 33: Non-Skyrmonic Magnetic Textures I

Time: Thursday 9:30–13:00 Location: H16

MA 33.1 Thu 9:30 H16

Anomalous quasielastic scattering in centrosymmetric helimagnets — N. D. Andriushin[1], J. Grumbach[1], A. A. Kulbakov[1], Y. V. Tymoshenko[2,1], Y. A. Onykiienko[1], R. Firouzmandi[3], E. Cheng[3], S. Granovsky[1], Y. Skourski[4], J. Ollivier[5], H. C. Walker[6], V. Kocsis[3], B. Büchner[3], M. Doerr[7], •D. S. Inosov[1], and D. C. Peets[1] — [1]IFMP, TU Dresden, Germany — [2]JCNS, FZ Jülich, Germany — [3]IFW Dresden, Germany — [4]HZDR, Dresden, Germany — [5]ILL, Grenoble, France — [6]ISIS, RAL, Didcot, UK — [7]MPI-FKF, Stuttgart, Germany

Centrosymmetric helimagnets which host spin helices or skyrmion-like topological spin structures comprise a distinct subclass of materials in which helical order is stabilized by bond frustration in contrast to the more common path of antisymmetric exchange interactions. Here we will present the spin-dynamical properties of the $SrFeO_3$ [1] and $Sr_3Fe_2O_7$ [2] perovskites. Inelastic neutron scattering reveals that with increasing temperature, high-energy magnons increasingly lose coherence, and the spin fluctuations become dominated by a distinct quasielastic component at low energies, concentrated at the ordering wave vectors. This quasielastic component likely originates from helical domain walls. We anticipate that this could be generic to all symmetric helimagnets in which the chiral symmetry is spontaneously broken by the magnetic order.

References:

[1] N. D. Andriushin *et al.*, arXiv:2409.10214 (2024).
[2] N. D. Andriushin *et al.*, npj Quant. Mater. **9**, 84 (2024).

MA 33.2 Thu 9:45 H16

Characterising 3D Topological Magnetic Textures using the Hopf index: Hopfions, Fractional Hopfions and Screw Dislocations — •Maria Azhar, Sandra Chulliparambil Shaju, Ross Knapman, Alessandro Pignedoli, and Karin Everschor-Sitte — Faculty of Physics and CENIDE, University of Duisburg-Essen.

In magnetic systems, twisted, knotted, linked, and braided vortex tubes manifest as Skyrmions, Hopfions, Fractional hopfions, or screw dislocations [1]. These complex textures are characterized by topologically non-trivial quantities, such as a Skyrmion number, a Hopf index H, a Burgers vector (quantified by an integer), and linking numbers.

We address the common challenges and pitfalls associated with numerically calculating H using the traditional Whitehead integral [2]. We present an alternative analytical method for determining H, introducing a new discrete geometric formulation [3]. This approach separates H into contributions from the self-linking and inter-linking of flux tubes of the emergent magnetic field.

Our analysis reveals the natural emergence of fractional Hopfions or textures with non-integer H, which we interpret as "mixed topology" states. These states can smoothly transform into one of several possible topological sectors with integer H. We establish a robust physical foundation for the Hopf index to assume integer, non-integer, or specific fractional values, depending on the system's underlying topology.

[1] M. Azhar, et al., PRL 128, 157204 (2022)
[2] R. Knapman, M. Azhar, et al., arxiv:2410.22058
[3] M. Azhar, et al., arXiv:2411.06929

MA 33.3 Thu 10:00 H16

Strain-induced spin spiral in Dy-doped Ferrite films — •Holger Meyerheim[1], Anupam Singh[1], Verena Ney[2], Andreas Ney[2], Arthur Ernst[2], Malleshwararao Tangi[1], Ilya Kostanovski[1], Manuel Valvidares[3], Pierluigi Gargiani[3], Jean-Marc Tonnerre[4], Stuart S. P. Parkin[1], and Katayoon Mohseni[1] — [1]MPI f. Mikrostrukturphysik, D-06120 Halle — [2]Johannes Kepler University, A-4040 Linz (Austria) — [3]ALBA Synchrotron, E-08290 Cerdanyola del Valles (Spain) — [4]Institut Neel, CNRS & Univ. J. Fourier, F-38042 Grenoble (France)

Ferrites are known as textbook ferrimagnets. Recent interest in oxides as low-dissipation materials in spintronics has also focused interest on the modification of the spin texture of oxides in general [1]. Here we present a combined experimental and theoretical study which shows that in 5-40 nm thick Dy-doped Ni-ferrite films the local structural strain and the resulting concomitant symmetry reduction induced by the large Dy^{3+} ions incorporated in the percent concentration range into the octahedral sites of the spinel-type structure leads to the emergence of the chiral Dzyaloshinskii-Moriya interaction (DMI). The DMI is responsible for the onset of a non-collinar spin texture. Using soft x-ray resonant magnetic reflectivity and x-ray magnetic circular dichroism experiments in the vicinity of the Fe- and Ni-$L_{2,3}$- and the Dy-$M_{4,5}$ edges we develop a model in which the Fe and Ni magnetic moments are aligned in a spiral-like spin texture with a q-vector almost parallel to [001]. This work is supported by the DFG under grant MO

4198/2-1. [1] L. Caretta, et al., Nat. Comm. 11, 1090 (2020)

MA 33.4 Thu 10:15 H16

Quantum Bloch points in magnetic systems — •Vladyslav Kuchkin, Štefan Liščák, Andreas Haller, Andreas Michels, and Thomas Schmidt — University of Luxembourg

A Bloch point represents a three-dimensional hedgehog singularity of a magnetic vector field in which the magnetization vanishes at the center. Experimentally, the appearance of such points is well-established; at the same time, the standard micromagnetic theory is only suitable for fixed-length continuous magnetization vector fields and is thus not applicable to such singularities. To approach this problem, we study a Bloch point in a quantum Heisenberg model for the case of spin-1/2 particles. Such a state can be stabilized by adding a Zeeman term that imposes a boundary condition. We obtain the ground state and the corresponding magnetization profile by performing an exact diagonalization and using density matrix renormalization group techniques. Our findings show a smooth change of the spin length in the quantum model, leading to zero magnetization at the Bloch point. This behavior is generic for different system sizes. Our results indicate the necessity of generalizing the classical micromagnetic model, relying on a magnetization vector field of constant length, by adding a third degree of freedom of the spin: the ability to change its length. We achieve this by introducing a regularized $\mathbb{S}^3$ model that describes a four-dimensional order parameter of unit length. In contrast to earlier attempts to describe magnetization profiles of varying lengths, our approach satisfies the quantum mechanical constraints on spin operators.

MA 33.5 Thu 10:30 H16

Magnetic solitons in hierarchical 3D magnetic nanoarchitectures of nanoflower shape — •Olha Bezsmertna[1], Rui Xu[1], Oleksandr Pylypovskyi[1], David Raftrey[2,3], Andrea Sorrentino[4], Jose A. Fernandez-Roldan[1], Ivan Soldatov[5], Daniel Wolf[5], Axel Lubk[5], Rudolf Schäfer[5], Peter Fischer[2,3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]University of California Santa Cruz, Santa Cruz CA, USA — [3]Lawrence Berkeley National Laboratory, Berkeley CA, USA — [4]Alba Light Source, Cerdanyola del Vallès 08290, Spain — [5]Leibniz Institute for Solid State and Materials Research, Dresden, Germany

Curvilinear magnetism is an emerging field that explores how magnetic properties and responses are modified in geometrically curved objects [1]. Here, we synthesize large-scale, highly-periodic 3D nanomembranes [2] of 50-nm-thick permalloy of a nanoflower shape interconnected by close-to-hemispherical indentations. Nanoflowers with a size of about 200 nm exhibit a variety of magnetic states, e.g. domain walls, flower, vortex and a state with two Bloch lines. The ground magnetic state is a vortex, which is shifted away from the geometric center of the nanoflower. Micromagnetic simulations show nonlocal symmetry breaking, which is specific to 3D curved geometries enabling interactions between surface and volume magnetostatic charges, responsible for the shift of the vortex [3]. [1] D. Makarov et al., Springer Nature, Vol. 146 (2022). [2] R. Xu et al., Nature Comm 2022. [3] O. Bezsmertna et al., Nano Lett., doi.org/10.1021/acs.nanolett.4c04584

MA 33.6 Thu 10:45 H16

Emergence of topological superconductivity in the presence of chiral magnetism in 2D $CrInTe_3$ — •Arnob Mukherjee[1], Fengyi Zhou[2], Soheil Ershadrad[1], Tanay Nag[3], Duo Wang[2], and Biplab Sanyal[1] — [1]Department of Physics and Astronomy, Uppsala University, Box-516, 75120 Uppsala, Sweden — [2]Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, 999078, China — [3]Department of Physics, BITS Pilani-Hyderabad Campus, Telangana 500078, India

We propose a framework for designing two-dimensional (2D) topological superconductors (TSCs) using a bilayer hybrid system of monolayer $CrInTe_3$ with noncoplanar magnetic textures coupled to a 2D s-wave superconductor. This hybrid system induces a topological superconducting phase, serving as a platform for realizing the 2D Kitaev model and supporting Majorana zero-energy modes via emergent p-wave pairing. Using Density functional theory calculations, we calculate the essential magnetic parameters, such as Heisenberg exchange and Dzyaloshinskii-Moriya interactions (DMI) using the LKAG approach. Large-scale Monte Carlo simulations reveal that the substantial DMI stabilizes a noncoplanar spiral magnetic state without external fields. In this phase, we observe a transition from dipolar to edge modes in the zero-energy local density of states as the chemical potential varies. Under finite magnetic fields, the system exhibits a mixed magnetic state with isolated skyrmions and spiral domain walls, leading to unique low-energy electronic states and insulating behavior.

MA 33.7 Thu 11:00 H16

Topological textures in antiferromagnetic thin-films stabilized by interfacial magnetostrictive destressing — •Lukas D Cavar[1], Julian Skolaut[2], Olena Gomonay[1], Simon J Sochiera[1], David Anthofer[1], Miela Gross[3], Evangelos Golias[4], Dirk Backes[5], Caroline A Ross[3], and Angela Wittmann[1] — [1]JGU, Mainz, DE — [2]IEAP, CAU, Kiel, DE — [3]MIT, Cambridge, USA — [4]MAX IV, Lund, SE — [5]DLS, Didcot, UK

Weakly-compensated antiferro- and ferrimagnets present us with ultrafast dynamics, along with a weak magnetization vector that is legible, accessible, and robust to external perturbations. This makes them ideal candidates for the next generation of computing materials, where information may be encoded in the form of topological magnetic textures. Conventional long-range interaction– namely, the stray field– is not sufficient to stabilize such textures on its own. Here we discuss the magnet-substrate interface, where a magnetostriction-dependent interfacial incompatibility gives rise to long-range destressing fields capable of stabilizing topological textures in easy-plane magnetic thin-films with nearly-compensating staggered spin ordering. We investigate two such materials– α-Fe_2O_3 (hematite) and dysprosium iron garnet (DyIG) near its compensation temperature– by x-ray magnetic linear dichroism microscopy and indeed observe a rich landscape of topological textures. Thereby we tread towards a rigorous understanding of the interfacial destressing field and begin to uncover a promising new source of topological mesostructure.

15 min. break

MA 33.8 Thu 11:30 H16

Towards stabilizing 360° domain walls in dysprosium iron garnet through magnetoelastic interactions — •Julian Skolaut[1,2], Lukas Cavar[1], Olena Gomonay[1], Miela Gross[3], Simon Sochiera[1], David Anthofer[1], Evangelos Golias[4], Dirk Backes[5], Caroline A. Ross[3], and Angela Wittmann[1] — [1]JGU, Mainz, DE — [2]present address: IEAP, CAU, Kiel, DE — [3]MIT, Cambridge, US — [4]MAX IV, Lund, SE — [5]DLS, Didcot, UK

Topologically protected magnetic textures, including 360° domain walls (DWs), are of considerable interest for next-generation data storage and computing technologies. Realizing such textures in ferri- and antiferromagnetic systems allows us to capitalize on these materials' intrinsic robustness to external perturbations and faster dynamics. However, well-established mechanisms, such as stray fields, cannot stabilize 360° DWs at zero magnetic field. Hence, we must turn to more exotic stabilization mechanisms. One promising candidate is magnetoelastic destressing mediated by the substrate/magnetic film interface. Here, we report the observation of 360° DWs in ferrimagnetic dysprosium iron garnet thin films. These topological DWs are present in applied magnetic fields from zero to above coercivity, suggesting topological protection, and can be manipulated using magnetic fields. Upon return to zero magnetic field, the initial state is not reproduced, indicating hysteresis. This hints toward stabilization via magnetoelastic interactions. Corroborating these results with insights from other materials and theory will further the understanding of exotic mechanisms, such as destressing fields, as a source of topological magnetic textures.

MA 33.9 Thu 11:45 H16

Computational studies of novel Dzyaloshinsky-Moriya interactions — •Samuel Holt[1,2], Martin Lang[1,2], Swapneel Pathak[1,2], and Hans Fangohr[1,2,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Faculty of Engineering and Physical Sciences, University of Southampton, Southampton SO17 1BJ, United Kingdom

The exploration of magnetic phases in chiral magnets has gathered significant interest due to the unique physics and potential applications of these materials. A key factor in these systems is the Dzyaloshinsky-Moriya interaction (DMI), which arises from the asymmetric environment of interacting magnetic spins and is linked to noncentrosymmetric crystallographic point groups. While a few point groups have had their DMI extensively studied, many remain unexplored.

In this talk, we systematically explore the multidimensional parameter space of these new DMI terms using micromagnetic simulations to identify and classify magnetic phases. Machine learning algorithms, such as clustering and autoencoders, are employed to automate this process, enabling the rapid identification and grouping of similar magnetic phases across extensive parameter spaces. Funded by EU Horizon 2020, grants 101152613 and 101135546.

MA 33.10 Thu 12:00 H16

Interplay between magnetic and charge order in an ultraclean van der Waals material — •Priya Baral[1], Sun Okumura[1], Moritz Hirschmann[2], Sebastian Esser[1], Rinsuke Yamada[1], Shun Akatsuka[1], Jonathan White[4], Samuel M. Moody[4], Stanislav Niktin[4], Nina-juliane Steinke[5], Shang Gao[6], Yoshichika Onuki[2], Taka-hisa Arima[2,7], Taro Nakajima[3], and Max Hirschberger[1,2] — [1]Department of Applied Physics, The University of Tokyo, Tokyo, JP — [2]RIKEN Center for Emergent Matter Science (CEMS), Saitama, JP — [3]Institute for Solid State Physics, University of Tokyo, Chiba, JP — [4]PSI Center for Neutron and Muon Sciences, Villigen PSI, CH — [5]Institut Laue-Langevin, 71 avenue des Martyrs, Grenoble, FR — [6]Department of Physics, University of Science and Technology of China, CHN — [7]Department of Advanced Materials Science, The University of Tokyo, JP

The interplay between charge-density wave order and magnetism has been a prominent area of research for decades, encompassing unconventional superconductors to more recent Kagome metals. The cooperative or competitive nature of these two phenomena has been a fundamental aspect of many-body physics. Recently, it has been demonstrated that RTe3 (R = rare earth) van der Waals materials exhibit helimagnetic textures coupled to an unconventional charge-density wave order. Here, we review recent developments in one of the ultra-clean members of the series, DyTe3. We reveal further evidence for the unconventional spin-charge coupling in this material by combining magnetic, transport and neutron scattering measurements.

MA 33.11 Thu 12:15 H16

Magnetic Ordering Temperature for Spin Spiral materials — •Varun Rajeev Pavizhakumari and Thomas Olsen — CAMD, Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby Denmark

Spin Spirals are the materials that show a helical arrangement of magnetic moments in the ground state. Thermal fluctuations from this state form collective excitations known as spin waves/magnons. As the thermal stability of a spin spiral is a decisive factor for its technological applications, there is considerable interest in the theoretical prediction of its critical temperature. This could be accomplished using two approaches - Holstein-Primakoff(HP) bosonization and the Green's function-Random Phase Approximation(RPA) where we can calculate the thermally renormalized magnon energies at each temperature. But these methods only exist for ferromagnetic and a few specific antiferromagnetic materials. In this work, we propose a single-Q spiral generalization of the HP bosonization and the Green's function-RPA to calculate the critical temperature. We benchmark these methods along with the classical Monte Carlo simulations and the Mean field theory, using their experimental exchange parameters for a diverse range of materials ; MnO and NiO(single site Neel state),MnF_2(altermagnetic),Cr_2O_3 and Fe_2O_3(two site Neel state) and $Ba_3NbFe_3Si_2O_{14}$(incommensurate). In all cases, we observe that the Green's function-RPA shows excellent agreement to the experiments and hence is as an ideal candidate to predict the critical temperature for any single-Q spirals.

MA 33.12 Thu 12:30 H16

Three-dimensional topological spin textures in curved chiral magnets — •Luke Turnbull[1,2], Max Birch[3], Marisel Di Pietro Martínez[1,2], Rikako Yamamoto[1,2], Jeffrey Neethirajan[1], Marina Raboni Ferreira[1,4], Rachid Belkhou[5], Simone Finizio[6], Dieter Suess[7], Geetha Balakrishnan[8], Claas Abert[7], Sebastian Wintz[9], and Claire Donnelly[3] — [1]MPI CPfS, Dresden, Germany — [2]WPI-SKCM2, Hiroshima, Japan — [3]RIKEN CEMS, Saitama, Japan — [4]Brazilian Synchrotron Light Laboratory, Sao Paulo, Brazil — [5]Synchrotron SOLEIL, Saint Aubin, France — [6]SLS, PSI, Villigen, Switzerland — [7]University of Vienna, Vienna, Austria — [8]Univeristy of Warwick, Coventry, UK — [9]HZB, Berlin, Germany

Nanoscale topologically non-trivial magnetization configurations generate significant interest due to both their fundamental properties, and their potential applications in ultra-efficient computing devices. While such textures have been widely studied in two dimensions, three dimensional (3D) ordering can yield more complex configurations, resulting in richer topologies and dynamic behaviours. However, reliably nucleating such 3D textures has proven challenging. Here, we achieve the controlled formation of a double helix ordering through the 3D nanopatterning of chiral single crystal helimagnets into nano-tori. We demonstrate that the interplay of intrinsic exchange interactions of the single crystal, with the extrinsic emergent effects of the patterned geometry, leads to the stabilisation of surface-localized topologically non-trivial double helices. Our approach has the potential to be applied to a wide range of quantum material systems.

MA 33.13 Thu 12:45 H16

Lifetime of toroidal Hopfions in bulk magnets with competing exchange interactions — •Moritz Sallermann[1,3], Hannes Jonsson[3], and Stefan Blügel[1,2] — [1]RWTH Aachen University, Germany — [2]PGI-1, Forschungszentrum Jülich, Germany — [3]University of Iceland, Iceland

Hopfions are three-dimensional topological solitons characterized by the Hopf invariant, which quantifies the pairwise linking number of constant magnetization pre-images. In simple models of bulk magnets with competing exchange interactions, Hopfions emerge as local energy minima in numerical simulations. However, to fully understand their stability against decay due to thermal fluctuations, merely identifying these local minima is insufficient. A more comprehensive understanding requires determining their expected average lifetimes. We employ the harmonic transition state theory framework, a computationally efficient yet approximate method, to estimate these lifetimes. This approach yields an Arrhenius-type expression comprising two key ingredients: the energy barrier and an entropic prefactor. The energy barrier represents the minimal energy needed to initiate decay, while the entropic prefactor measures the relative entropy of the energy bottleneck, compared to the configuration space volume of the local minimum. We present our findings on the lifetimes of Hopfions in these systems and discuss technical challenges encountered, such as the treatment of Goldstone modes and the computation of sparse positive-definite determinants.

We acknowledge funding from the ERC grant "3D MAGIC".

MA 34: Molecular Magnetism

Time: Thursday 9:30–12:45 Location: H18

MA 34.1 Thu 9:30 H18

Handling higher order ligand field parameters of single molecule magnets using deep learning — •Zayan Ahsan Ali, Julius Mutschler, Preeti Tewatia, and Oliver Waldmann — Physikalisches Institut, Universität Freiburg, D-79104 Freiburg, Germany

In recent decades, Single Molecule Magnets (SMMs) have sparked an interest not only due to their applications in quantum computing and spintronics, but also as an ideal platform for exploring fundamental principles of quantum magnetism. While substantial progress has been made towards the characterization of magnetic properties of 3d SMMs, the study of 4f SMMs remains challenging. This difficulty arises from the involvement of up to 27 ligand field parameters and the typically featureless nature of experimental magnetic data, leading to severe overparameterization. Moreover, the physically relevant regions in this parameter space are mostly unknown a priori. Although deep learning based inverse models, such as Conditional Variational Autoencoders and Invertible Neural Networks, have shown promise in addressing overparameterization, their performance degrades significantly when trained on uninformative parameter spaces, which dominate especially in high dimensional settings. This work investigates the use of Monte Carlo based parameter sampling for the higher order ligand field parameter space as a crucial precursor towards improving the deep learning inverse models. The resulting dataset represents a more informative prior, enabling insights into the effects of higher order ligand field parameters and the correlations between them.

MA 34.2 Thu 9:45 H18

Polarization of Electron Spin and Orbitals in Chiral Molecular Junctions on Semiconductors — •Peng Xiong[1], Yuwaraj Adhikari[1], Tianhan Liu[1,3], Hailong Wang[2], Zhenqi Hua[1], Haoyang Liu[1], Paul Weiss[3], Binghai Yan[4], and Jianhua Zhao[2] — [1]Florida State University, USA — [2]Institute of Semiconductors, Chinese Academy of Sciences, China — [3]University of California, Los Angeles, USA — [4]Weizmann Institute of Science, Israel

Electrical generation and transduction of polarized electron spins in semiconductors via nonmagnetic means are of broad interest in spintronics and quantum information science. One such pathway is chirality-induced spin selectivity (CISS), where real-space structural chirality induces spin polarization of electrons from a nonmagnetic electrode. We have studied the CISS effect through measurement of spin-selective transport in chiral molecular junctions comprising a nonmagnetic normal metal electrode and a self-assembled monolayer of chiral molecules on magnetic (GaMnAs) or nonmagnetic (n-GaAs) semiconductors, where the spin polarization is detected via the spin-valve conductance and Hanle effect, respectively. The results reveal several important characteristics of the CISS effect [1-3]: i) nontrivial linear-response magnetoconductance in two-terminal CISS spin valves, in apparent violation of the Onsager reciprocal relation; ii) crucial role of the spin-orbit coupling in the normal metal electrode, suggesting the importance of orbital polarization in the chiral molecules; iii) spin generation by CISS in semiconductors. 1. ACS Nano 14, 15983 (2020); 2. Nat. Commun. 14:5163 (2023) ; 3. Ad. Mater. 36, 2406347 (2024).

MA 34.3 Thu 10:00 H18

Effects of Boundary Condition on Quantization in the Spin-1/2 Heisenberg Chain — •Saketh Ravuri[1], Chenxiao Zhao[1], Pascal Ruffieux[1], and Roman Fasel[1,2] — [1]Empa, Dübendorf, Switzerland — [2]University of Bern, Bern, Switzerland

The spin-1/2 antiferromagnetic Heisenberg chain resides in a gapless spin liquid phase in the thermodynamic limit. In finite-length systems, however, quantization introduces a length-dependent excitation gap, which is further influenced by the boundary conditions. In this work, we investigate how open and periodic boundary conditions affect the quantization and gap behavior in spin-1/2 antiferromagnetic Heisenberg chains constructed by covalently linking magnetic nanographene units. For chains of fixed length, we demonstrate that open boundary conditions result in a smaller gap compared to periodic boundary conditions, as clearly evidenced by the inelastic electron tunneling spectra. This impact of boundary conditions diminishes with increasing chain length and vanishes in the thermodynamic limit. Moreover, in periodic rings with odd-numbered units, we investigated the scattering of a single spinon caused by J-fluctuations. These findings illuminate the role of boundary effects in finite-size quantum spin systems and contribute to the fundamental understanding of quantum magnetism and excitations in spin chains.

MA 34.4 Thu 10:15 H18

Approximate finite-temperature Lanczos modelling of dysprosium containing magnetic molecules — •Jürgen Schnack and Dennis Westerbeck — Bielefeld University, Faculty of Physics, 33615 Bielefeld

Dysprosium containing magnetic molecules are considered promissing building blocks of future quantum technology such as storage, quantum computing, quantum sensing, or magnetocalorics. The initial physical characterization includes measurements of magnetization or heat capacity as function of temperature and applied magnetic field.

A theoretical modelling of an approximate quantum spin model by means of exact diagonalization of multicenter systems is virtually impossible due to the large magnetic moment of dysprosium. We resort to the finite temperature Lanczos method which however converges rather slowly [1]. We explain the reasons, our solutions and results for recent Dy containing molecules [2].

[1] O. Hanebaum and J. Schnack, Eur. Phys. J. B, 87, 194, 2014.

[2] D. Westerbeck, Ph.D. thesis, Bielefeld University, 2025, in preparation.

MA 34.5 Thu 10:30 H18

Annealing Induced Ordered Structures of H2Pc Monolayer on γ'-Fe4N Thin Film — •Hiroki Ono[1], Yoshitaka Umeda[1], Kaito Yoshida[1], Kenzaburo Tsutsui[1], Kohei Yamamoto[2], Osamu Ishiyama[2], Toshihiko Yokoyama[2], Masaki Mizuguchi[1], and Toshio Miyamachi[1] — [1]Nagoya University, Nagoya, Japan — [2]Institute for Molecular Science, Okazaki, Japan

Organic-inorganic hybrid interface has been studied because its interfacial spin state can be controlled through proximity effect. Spin state depends on local interface structures as well as electronic interaction between organic molecules and magnetic substrates. Therefore, controlling the interface structure is essential but remains challenging because of strong interaction between organic and inorganic materials.

In this work, we fabricate organic-inorganic hybrid thin films using iron nitride as a ferromagnetic substrate and phthalocyanine(H2Pc) as an organic molecule. Iron nitride atomic layers with γ'-Fe4N stoichiometry uniformly grow and show weaker interaction than typical ferromagnetic substrate. Therefore, γ'-Fe4N is a candidate to create structurally controlled interface. We investigate interface structure by using scanning tunneling microscopy(STM) and low energy electron diffraction(LEED), and electronic/magnetic properties by using x-ray absorption spectroscopy/magnetic circular dichroism(XAS/XMCD). We confirm the magnetic coupling occurs at H2Pc/γ'-Fe4N bilayer interface from XAS/XMCD results. H2Pc monolayer on γ'-Fe4N bilayer do not have any long-range lattice manner. But, we find annealing induces well-ordered structure while preserving interface magnetic coupling.

MA 34.6 Thu 10:45 H18

CuCu4 metallacrowns on the Au(111) surface: A density functional study — •Ariyan Tavakoli[1], Stefan Lach[1], Benjamin Stadtmüller[2], Christiane Ziegler[1], Peter Puschnig[3], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]Experimentalphysik II, Institute of Physics, Augsburg University, Augsburg, Germany — [3]Department of Physics, University of Graz, Graz, Austria

Metallacrowns [1] combine chemical and structural features that make them a promising material system for single-molecule magnets. Here, we present a first-principles study of the electronic and magnetic properties of the metallacrown (HNEt3)2CuII [12-MCYN(Shi)-4] (Y=CuII), in short CuCu4, in the gas phase and on the Au(111) surface. First, we study the magnetic properties of CuCu4 metallacrown in the gas phase by applying the broken symmetry approach [2], where we benchmark the performance of various (range-separated) hybrid functionals compared to the computationally cheaper GGA+U approach. In the second step, we explore the magnetic configurations of CuCu4 metallacrown adsorbed on an Au(111) surface using den-

sity functional theory (DFT) with GGA+U framework. The analysis highlights the changes of the ligand structure and the density of state (DOS) around the metal centers by a comparison between the isolated molecule and the adsorbed one on the surface.

[1] B. R. Gibney et al., Inorganic Chemistry 33 (1994). [2] Pavlyukh, Y. et al., PhysRevB. 99, 144418 (2019).

15 min. break

MA 34.7 Thu 11:15 H18

Cooperative and Selective Redox Doping Switches Single-Molecule Magnetism — Fabian Paschke[1], Matteo Briganti[2], Vivien Enenkel[1], Tobias Birk[1], Jan Dreiser[3], Peter Schmitt[4], Rainer F. Winter[4], Federico Totti[2], and •Mikhail Fonin[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Department of Chemistry 'Ugo Schiff' and INSTM Research Unit, University of Florence, 50019 Sesto Fiorentino, Italy — [3]Swiss Light Source, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland — [4]Fachbereich Chemie, Universität Konstanz, 78457 Konstanz, Germany

The controlled manipulation of electronic and magnetic states in single-molecule magnets (SMMs) is crucial for their implementation in molecular spintronics. In typical SMMs, key properties like magnetic anisotropy and slow magnetic relaxation are imposed by complex ligand shells, whose bulky and three-dimensional structures hamper efficient manipulation of the molecular magnetism by chemical methods. Here, we demonstrate highly selective chemical doping of an Fe_4 nanomagnet on a Pb(111) surface using lithium atoms. Scanning tunneling microscopy, X-ray absorption spectroscopy, and ab initio calculations reveal the cooperative incorporation of three Li atoms per Fe_4 molecule, resulting in a selective, threefold reduction of its iron-based magnetic core. The doping modifies the intramolecular exchange interaction, turning from antiferromagnetic to ferromagnetic coupling, and changes the molecular magnetic anisotropy from easy-axis to easy-plane.

MA 34.8 Thu 11:30 H18

Tuning spin-injection into metallacrown/thin-metal film systems — •David Anthofer[1], Ashish Moharana[1], Dominik Laible[2], Fabian Kammerbauer[1], Alexander Hagenow[2], Eva Rentschler[2], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg Universität Mainz, Deutschland — [2]Department Chemie, Johannes-Gutenberg Universität Mainz, Deutschland

Single-molecular magnets (SMMs) have recently gained significant interest due to their ability to retain magnetic information at the molecular level, offering potential applications in high-density data storage devices. A crucial challenge hindering their application in technology is the integration with thin-film devices. To tackle this challenge, we explore the spin-injection efficiency in hybrid molecule/non-magnetic metal thin film heterostructures to understand the impact of hybridization. For this, we utilize molecules based on the metallacrown system, chosen for their unique combination of synthetic versatility and structural stability. We inject a pure spin current at ferromagnetic resonance into the hybrid interface, allowing us to measure the magnetic damping of the system. We observe a notable increase in damping after adsorption of Dysprosium-based metallacrown SMMs. In contrast, no change in damping was observed after deposition of Copper-based metallacrowns indicating the significance of molecular composition on the spin-injection efficiency at the hybrid interface. Further optimization of the ferro- and nonmagnetic metal layer thicknesses proves to affect the observed change in damping, paving the path toward a sensitive framework to study hybridization at the molecule/metal interface.

MA 34.9 Thu 11:45 H18

Probing magnetic exchange interactions in cobalt-based molecular magnets using magneto-Raman spectroscopy — •Komalavalli Thirunavukkuarasu[1], David Hunger[2], Julia Netz[3], Duncan Moseley[4], Ziling Xue[4], Dmitry Smirnov[5], Andreas Koehn[3], and Joris van Slagaren[2] — [1]Department of Physics, Florida A & M University, Tallahassee, FL, USA — [2]Institute of Physical Chemistry, University of Stuttgart, Stuttgart, Germany — [3]Institute of Theoretical Chemistry, University of Stuttgart, Stuttgart, Germany — [4]Department of Chemistry, University of Tennessee, Knoxville, USA — [5]National High Magnetic Field Laboratory, Tallahassee, USA

Combining spectroscopy with one or more external parameters such as low temperature, high pressure, and high magnetic fields, allows us to probe interplay between spin, charge, orbital, and lattice degrees of freedom. Spin exchange interactions play an important role in single-molecule magnets and molecular qubits that feature magnetic bistability. However, there have been few detailed studies to experimentally find the energy scale of these interactions such as spin-phonon coupling. Recently, we employed magneto-Raman spectroscopy together with theoretical work on single molecular magnets to reveal the signatures of spin-phonon interactions in these materials. In this talk, the magneto-Raman experimental results from mononuclear cobalt(II) and radical-bridged dinuclear cobalt(II) complexes and the outcome will be discussed.

MA 34.10 Thu 12:00 H18

The Role of Quantum Vibronic Effects in the Spin Polarization of Charge Transport through Chiral Molecular Junctions — •Samuel Rudge[1], Christoph Kaspar[1], Riley Preston[1], Joseph Subotnik[2], and Michael Thoss[1] — [1]Institute of Physics, University of Freiburg — [2]Department of Chemistry, Princeton University

The chirality-induced spin selectivity (CISS) refers to the experimentally observed phenomenon that the transport of spin-polarized electrons through chiral mediums can be highly asymmetric between the two spin orientations and enantiomers [1]. Although the exact mechanism underpinning the CISS effect is still unknown, one of the leading ideas is that it is connected to the coupling of transport electrons to molecular vibrations. In this contribution, we follow this theme by investigating CISS in the context of charge transport through a chiral molecular nanojunction via the numerically exact, fully quantum hierarchical equations of motion (HEOM) approach [2]. Specifically, we calculate charge currents through a two-site, two-mode model [3], focusing on the highly nonadiabatic regime of low-voltage charge transport, in which we find significant spin polarization.

[1] R. Naaman and D. H. Waldeck, Annu. Rev. Phys. Chem. **66**, 263-281 (2015)

[2] C. Schinabeck, A. Erpenbeck, R. Härtle2, and M. Thoss, Phys. Rev. B **94**, 201407(R) (2016)

[3] H.-H. Teh, W. Dou, and J. Subotnik, Phys. Rev. B **106**, 184302 (2022)

MA 34.11 Thu 12:15 H18

Chiral-induced unidirectional spin-to-charge conversion — •Ashish Moharana[1], Yael Kapon[2,3], Fabian Kammerbauer[1], David Anthofer[1], Shira Yochelis[2,3], Mathias Klaüi[1], Yossi Paltiel[2,3], and Angela Wittmann[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Mainz 55128, Germany — [2]Institute of Applied Physics, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel — [3]Center for Nanoscience and Nanotechnology, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel

The chiral-induced spin selectivity (CISS) effect has recently gained significant attention in the field of spintronics. The remarkably high efficiency of the spin polarizing effect has recently gained substantial interest due to the high potential for future sustainable hybrid chiral molecule magnetic applications. While so far research has predominantly focused on transport properties, 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 interfacial spin-orbit coupling in chiral molecule/metal thin film heterostructures by probing the chirality and spin-dependent spin-to-charge conversion. Our findings validate the central role of spin angular momentum for the CISS effect, paving the path toward the functionalization of hybrid molecule-metal interfaces via chirality.

MA 34.12 Thu 12:30 H18

Interplay between spin induced polarization and quantum entanglement in triangular magnetic molecules — •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 35: PhD Focus Session: Using Artificial Intelligence Tools in Magnetism

Over the last decade, the field of artificial intelligence (AI) has experienced significant growth and progressively offers applications across a wide range of topics, becoming an integral part of our daily lives. Its importance was also underscored by the 2024 Nobel Prize in Physics awarded to John J. Hopfield and Geoffrey E. Hinton 'for foundational discoveries and inventions that enable machine learning with artificial neural networks'. The application of AI methods is also becoming increasingly relevant in research for prediction and data analysis to enhance research, making it faster and more efficient. Typically, these AI tools come from the domain of machine learning, centered on deep learning architectures such as neural networks, convolutional neural networks, and transformer networks. To ensure young researchers, especially in the field of magnetism, can benefit from this progress, we organize the PhD Focus session 'Using Artificial Intelligence Tools in Magnetism'. In this session, experts will demonstrate in highly pedagogical presentations how AI tools can be applied in material science and magnetism. Additionally, there will be a direct, practical introduction to this area of AI tools in magnetism with a hands-on part, where each participant can engage and explore the fascinating world of AI tools for magnetism firsthand using a prepared repository. You can find the repository at https://github.com/kfjml/AI-Magnetism-Session-Regensburg-2025 , please follow the instructions in the Readme, ideally before the session. Alternatively, you can download the repository as a ZIP file, including the instructions in the Readme, from https://download.klaeui-lab.de/AI-Magnetism-Session-Regensburg-2025.

Organizers: Kilian Leutner, kileutne@students.uni-mainz.de; Thomas B. Winkler, thomas.winkler@ru.nl; Robin Msiska, robin.msiska@uni-due.de; Kübra Kalkan, kuebra.kalkan@uni-due.de, Jan Maskill, maskill@rptu.de

Time: Thursday 9:30–13:00 Location: H20

Introduction

Invited Talk MA 35.1 Thu 9:35 H20

Artificial Intelligence for Materials Science: Critical Importance of Rare Events, Active Learning, and Uncertainties — •Matthias Scheffler — The NOMAD Laboratory at the Fritz Haber Institute of the Max Planck Society, 14195 Berlin, DE

Materials properties are often governed by an intricate interplay of many processes. As a consequence, the description in terms of meaningful analytical equations is typically inappropriate, and we are promoting the concept of 'materials genes'. These are elemental materials features that 'correlate' with the materials property of interest. Thus, they address the full intricacy and describe (in a statistical sense) the material's property and function.[1]

AI and machine learning (ML) exhibit diminished reliability when entering uncharted data regions. When the training data are representative of the full population (or iid), extrapolation may work. However, for materials this requirement is hardly fulfilled. Still, materials scientists are searching for 'statistically exceptional' situations, and properties are often triggered by 'rare events' that are not or not well covered by the available data, or smoothed out by the ML regularization. This all implies caution when applying ML. In my talk I will explain these issues and routes toward solutions. Key issues are the 'range of applicability' of ML models, the awful overconfidence of prediction uncertainties, and the needs for active learning.

(**) In collab. with Lucas Foppa, Kisung Kang, and Akhil S. Nair.

1) Scheffler M AI guided workflows for screening the materials space. Coshare Science 02, 02 (2024); https://doi.org/10.61109/cs.202403.129

Invited Talk MA 35.2 Thu 10:05 H20

Physics meets data: decoding magnetic inhomogeneities through latent analysis — •Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen

Physicists are trained to simplify complex problems into their fundamental components, often using effective minimal models to describe experimentally observed phenomena. This approach's standard challenges include the difficulty of directly measuring model parameters and the frequent oversimplification or neglect of sample inhomogeneities. As a result, models often fail to make accurate predictions when critical effects are overlooked or inadequately represented. In contrast, data-driven approaches focus on learning directly from the data, ideally without making restrictive assumptions about the data. This talk addresses the problem of hidden features in data and presents computationally efficient, physics-inspired data analysis tools - latent entropy and latent dimension [1,2] - that, for example, allow uncovering magnetic inhomogeneities from video data.

[1] I. Horenko, D. Rodrigues, T. O'Kane, K. Everschor-Sitte, Communications in Applied Mathematics and Computer Science 16, 2 (2021). [2] D. Rodrigues, K. Everschor-Sitte, S. Gerber, I. Horenko, iScience 24, 3 (2021).

Invited Talk MA 35.3 Thu 10:35 H20

AI used for micromagnetic simulations — •Thomas Schrefl[1], Felix Lasthofer[1], Qais Ali[1], Heisam Moustafa[2], Harald Oezelt[2], Alexander Kovacs[2], Masao Yano[3], Noritsugu Sakuma[3], Akihito Kinoshita[3], Tetsuya Shoji[3], and Akira Kato[3] — [1]Christian Doppler Laboratory for magnet design through physics informed machine learning, Wiener Neustadt, Austria — [2]University for Continuing Education Krems, Wiener Neustadt, Austria — [3]Advanced Materials Engineering Division, Toyota Motor Corporation, Susono, Japan

Micromagnetic simulations are an excellent means for prediction of magnetic properties. However, the required computational resources limit the use of micromagnetics for materials design. Machine learning models can serve as surrogate for evaluating target properties during optimization. Artificial intelligence can sort pictures based on content or create new images given keywords. Treating the magnetization distribution as an image, methodologies from image processing can be applied in magnetism. We used this approach to predict the magnetization dynamics of thin film elements. The magnetic states are encoded by a convolutional neural network. For bulk magnets a different approach is required. Their three-dimensional grain structure can be represented by a graph. The regular pixels are replaced by the nodes and edges of a graph. We applied graph neural networks to predict hysteresis properties of permanent magnets. Trained machine learning models can be used for inverse design. Given certain targets, optimized magnets are suggested.

10 min break

Invited Talk MA 35.4 Thu 11:15 H20

Future method for estimating parameters in magnetic films using machine learning — •Kenji Tanabe — Toyota Technological Institute, Nagoya, Japan

Estimating material parameters in fabricated materials is a crucial experiment in the field of materials science. Some parameters are difficult or time-consuming to measure. In spintronics, parameters such as the Dzyaloshinskii-Moriya exchange constant are good examples of this. If these parameters could be easily and quickly estimated, our research field would grow rapidly. Here, we present a new method for estimating parameters in magnetic films from a magnetic domain image using machine learning. A magnetic structure is well-known to be deeply related to magnetic parameters. Although a complicated magnetic structure, which often appears in an as-grown magnetic film, is considered random by human eyes, it is influenced by several magnetic energies. Thus, the characteristics of such parameters are probably hidden in the random magnetic structure. Such a relationship suggests that parameters can be estimated from a magnetic domain image by using pattern recognition. We collected a huge number of datasets of magnetic parameters and magnetic domain images made by micromagnetic simulation and/or taken by magnetic microscopes. The datasets were used as training and test data for the convolution neural network, which is a famous technique in machine learning for pattern recognition. We succeeded in the estimation of the parameters from the magnetic image using machine learning. This result may relieve future researchers from the difficulty of measuring parameters.

MA 35.5 Thu 11:45 H20

Hands-on workshop for using AI in magnetism research — •Kilian Leutner[1], Thomas B. Winkler[2], Jan Maskill[3], Kübra Kalkan[4], and Robin Msiska[4] — [1]Institute of Physics, Johannes Gutenberg-University Mainz — [2]Institute for Molecules and Materials, Radboud University — [3]Department of Physics, University of Kaiserslautern-Landau — [4]Faculty of Physics, University of Duisburg-Essen

In this workshop, participants will receive a practical introduction to applying artificial intelligence (AI) in magnetism research. As a hands-on session, everyone can actively engage. We will demonstrate how to automatically analyze magneto-optical Kerr microscopy images of magnetic skyrmions using AI. The critical and significant step in the analysis involves segmenting the Kerr images using the Skyrmion U-Net, a convolutional neural network [1]. The participants will use their own devices to explore a repository, learning and executing the steps necessary to train and apply a skyrmion U-Net model. The required experimental Kerr data, pre-trained Skyrmion U-Net models, and code are available in a repository at https://github.com/kfjml/AI-Magnetism-Session-Regensburg-2025 or can be downloaded as a ZIP file from: https://download.klaeui-lab.de/AI-Magnetism-Session-Regensburg-2025. Please follow the instructions in the Readme file prior to the session, to make most use of it. This presented approach, is adaptable to other magnetic textures or imaging methods and can also be applied beyond magnetism.

[1] I. Labrie-Boulay et al., Phys. Rev. Applied 21, 014014 (2024)

MA 36: Focus Session: Ising Superconductivity in Monolayer Transition Metal Dichalcogenides (joint session TT/HL/MA)

Superconducting monolayer transition metal dichalcogenides (TMDs) like $NbSe_2$, TaS_2, and gated WSe_2 or MoS_2, have attracted lot of interest in recent years. On the one hand Ising spin-orbit coupling pins the electron's spin out of plane, and hence is responsible for critical in-plane magnetic fields by far exceeding the Pauli limit. On the other hand, while the underlying pairing mechanism is still under debate, recent experiments provide strong evidence for its unconventional, multiband, nature. The Focus Session will feature experimental and theoretical advances on the superconductivity in monolayer TMDs, with focus on universal features, a possible Luttinger-Kohn mechanism, a nodal or even chiral nature of the gap functions, and their phase diagram.

Organizers: Milena Grifoni (Universität Regensburg), Julian Siegl (Universität Regensburg)

Time: Thursday 9:30–12:45 Location: H36

Topical Talk MA 36.1 Thu 9:30 H36

Evidence of Unconventional Superconductivity in Monolayer and Bulk van der Waals Material TaS_2 — •Somesh Chandra Ganguli[1], Viliam Vano[1,2], Yuxiao Ding[1], Maryam Khosravian[1], Jose Lado[1], and Peter Liljeroth[1] — [1]Department of Applied Physics, Aalto University FI-00076 Aalto, Finland — [2]Joseph Henry Laboratories and Department of Physics, Princeton University, Princeton, NJ, USA

Unconventional superconductors are at the forefront of modern quantum materials' research. Even though unconventional superconductivity has been discovered in a large number of bulk systems, intrinsic unconventional superconductivity in the monolayer limit has remained elusive.

In our work, we demonstrate the evidence of nodal f-wave superconductivity in monolayer 1H-TaS_2. We also observe the emergence of many-body excitations potentially associated to its unconventional pairing mechanism. Furthermore, the nodal f-wave superconducting state in the pristine monolayer 1H-TaS_2 is driven to a conventional gapped s-wave state by the inclusion of non-magnetic disorder. I will also briefly describe our recent results on bulk layered superconductor 6R-TaS_2 where alternating metallic and Mott insulating layers gives rise to unconventional superconductivity.

Our results demonstrate the emergence of unconventional superconductivity in van der Waals (vdW) materials and therefore opens possibilities to create designer unconventional superconductivity in vdW heterostructures.

Topical Talk MA 36.2 Thu 10:00 H36

Signatures of Unconventional Superconductivity in Transition Metal Dichalcogenides — •Miguel Ugeda — Donostia International Physics Center, San Sebastián, Spain

Lowering the dimensionality of a material is an effective strategy to boost electronic correlations that fail to be captured by conventional pictures. In this arena, two-dimensional (2D) materials provide an ideal platform for the exploration of quantum collective phenomena arising from such strong interactions due to their simple synthesis and modelling. In this talk, I will review the rich physics that emerges in the family of transition metal dichalcogenide (TMD) metals in the superconducting state in the 2D limit. While many of these TMD metals exhibit superconductivity in both the bulk form down to the monolayer, the latter limit stores exciting surprises beyond the BCS frameworks that have been revealed in the last years. I will focus on our $NbSe_2$, the most representative TMD superconductor, where I will describe our recent STM/STS experiments. Lastly, I will briefly describe our current efforts to induce unconventional superconductivity in more complex TMD heterostructures.

Topical Talk MA 36.3 Thu 10:30 H36

Friedel Oscillations and Chiral Superconductivity in Monolayer $NbSe_2$ — •Magdalena Marganska[1,2], Julian Siegl[1], Anton Bleibaum[1], Marcin Kurpas[3], Wen Wan[4], John Schliemann[1], Miguel M. Ugeda[4,5], and Milena Grifoni[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93 053

Regensburg — [2]Institute for Theoretical Physics, Wrocław University of Science and Technology, Wyb. Wyspiańskiego 27, 50-370 Wrocław, Poland — [3]Institute of Physics, University of Silesia in Katowice, 41-500 Chorzów, Poland — [4]Donostia International Physics Center, Paseo Manuel de Lardizábal 4, 20018 San Sebastián, Spain — [5]Ikerbasque, Basque Foundation for Science, Bilbao 48013, Spain

In 1965 Kohn and Luttinger proposed a mechanism for superconductivity, based on the electronic Coulomb interaction alone. The screening effects, which cause Friedel oscillations of charge density around impurities, modulate also the interaction between moving electrons. If it has attractive regions, superconductivity can arise by exploiting them. This mechanism, negligible in 3D metals, can become much stronger in 2D electronic systems. In a monolayer of $NbSe_2$ the screening is further suppressed, due to the multi-orbital nature of the electronic band at the Fermi level. We show how this, and the presence of K/K' Fermi surfaces, leads to superconducting pairing. The dominant gap solution at $T = 0$ has the chiral p+ip symmetry. It evolves with increasing temperature, turning from fully chiral at T=0 to a nematic solution with p-like symmetry close to the critical temperature. Our results are also consistent with our tunneling spectroscopy measurements in $NbSe_2$.

15 min. break

Topical Talk MA 36.4 Thu 11:15 H36

Unconventional Pairing in Ising Superconductors — •Andreas Kreisel[1], Subhojit Roy[2,3,4], Brian M. Andersen[1], and Shantanu Mukherjee[2,3,4] — [1]Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark — [2]Department of Physics, Indian Institute of Technology Madras, Chennai, 600036, India — [3]Center for Atomistic Modelling and Materials Design, IIT Madras, Chennai 600036, India — [4]Quantum Centers in Diamond and Emergent Materials (QCenDiem)-Group, IIT Madras, Chennai, 600036 India

Ising spin orbit coupling arises in materials with non-centrosymmetric crystal structure in conjunction of an in-plane mirror symmetry and is realized in some two dimension transition metal dichalcogenides. Example materials are monolayer $NbSe_2$, MoS_2, TaS_2, and $PbTe_2$, where signatures of unconventional superconductivity are found in contrast to their three dimensional bulk counterparts. In this talk, I present a microscopic formalism to calculate the superconducting instability from a momentum-dependent spin- and charge-fluctuation-mediated pairing interaction in presence of spin orbit coupling that induces a spin splitting. This pairing is then applied to the electronic structure of transition metal dichalcogenides. We provide a quantitative measure of the mixing between the even- and odd-parity superconducting states which varies with Coulomb interaction. The pairing scenario from spin fluctuations together with the mixing of the odd-parity superconducting state gives rise to an enhancement of the critical magnetic field.

Topical Talk MA 36.5 Thu 11:45 H36

High-Field Study of Ising Superconductivity in TMDs — •Oleksandr Zheliuk[1,2], Xiaoli Peng[3], Andrew Ammerlaan[1,2], Puhua Wan[3], Yulia Kreminska[3], Steffen Wiedmann[1,2], Uli Zeitler[1,2], and Jianting Ye[3] — [1]High Field Magnet Laboratory (HFML-EMFL), Radboud University, Toernooiveld 7, Nijmegen 6525 ED, The Netherlands — [2]Radboud University, Institute for Molecules and Materials, Nijmegen 6525 AJ, The Netherlands — [3]Zernike Institute for Advanced Materials, University of Groningen, 9747 AG Groningen, The Netherlands

Semiconducting transition metal dichalcogenides are known for their strong spin-orbit coupling, the possibility of hosting a variety of quantum phases such as two-dimensional superconductivity with upper critical fields that by far bypasses the Pauli limit, Josephson coupled states, and high mobility electron gasses accessed in electric double-layer transistor (EDLT) configuration. Despite its well-established electronic structure, the dome-shaped superconducting phase diagram where the critical temperature T_c can be modulated by carrier concentration is yet to be understood. This talk will sharpen the understanding of the electronic structure of the electron-doped MoS_2, covering recent insights into superconductivity in MoS_2 probed via the multivalley transport phenomena accessed in high magnetic field.

MA 36.6 Thu 12:15 H36

Unconventional Pairing in Ising Superconductors: Application to Monolayer NbSe$_2$ — •Subhojit Roy[1], Andreas Kreisel[2], Brian Andersen[3], and Shantanu Mukherjee[4] — [1]Indian Instititute of Technology Madras, Chennai, 600036, India — [2]Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark — [3]Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark — [4]Indian Instititute of Technology Madras, Chennai, 600036, India

The presence of a non-centrosymmetric crystal structure and in-plane mirror symmetry allows an Ising spin-orbit coupling to form in some two-dimensional materials, where a nontrivial nature of the superconducting state is currently being explored. In this study(1), we develop a microscopic formalism for Ising superconductors that captures the superconducting instability arising from a momentum-dependent spin- and charge-fluctuation-mediated pairing interaction. We apply our pairing model to the electronic structure of monolayer $NbSe_2$, where first-principles calculations reveal the presence of strong paramagnetic fluctuations. Our calculations provide a quantitative measure of the mixing between the even- and odd-parity superconducting states and its variation with Coulomb interaction. Further, numerical analysis in the presence of an external Zeeman field reveals the role of Ising spin-orbit coupling and mixing of odd-parity superconducting state in influencing the low-temperature enhancement of the critical magnetic field.

[1] S. Roy et al., 2D Mater. 12 015004 (2025).

MA 36.7 Thu 12:30 H36

Emergence of Unconventional Superconductivity and Doped Mott Physics in 6R-TaS$_2$ — •Yuxiao Ding[1], Amritroop Achari[2], Jonas Bekaert[3], Jose Lado[1], Rahul R. Nair[2], Peter Liljeroth[1], and Somesh C. Ganguli[1] — [1]Aalto University, Finland — [2]University of Manchester, UK — [3]University of Antwerp, Belgium

Discovery of Unconventional superconductivity in van der Waals (vdW) materials have brought about a paradigm shift in modern condensed matter research for their tunability and potential application in quantum computing. Among these, most prevalent are 4Hb-TaS_2 and 6R-TaS_2. They comprise of alternating Mott insulating and metallic layers and give rise to exotic quantum states such as topological superconductivity, anomalous Hall effect potentially associated with hidden magnetism etc. We have studied, using low temperature STM/STS, the newly discovered vdW superconductor 6R-TaS_2. For the 1T phase, a doped Mott phase was observed with potential charge order occurring due to hybridisation between 1T and underlying 1H layer. We also observe Kondo sites in the half-filled regime, which unlike 4Hb-TaS_2, were more robust under the application of tip-induced electric field. This indicates significantly different interlayer interactions in these two systems. We also observe evidence of unconventional superconductivity in the 1H phase, indicated by the presence of V-shaped superconducting gap and many-body excitations. Our results pave a new direction in understanding the role of interplay between magnetism and superconductivity in layered unconventional superconductors.

MA 37: Magnetic Imaging Techniques

Time: Thursday 15:00–17:45 Location: H16

MA 37.1 Thu 15:00 H16

Magnetic particle spectroscopy of ferrite nanoparticles: Controlling the Néel to Brownian relaxations — •Ondřej Kaman[1], Tereza Voltrová[1,2], Lenka Kubíčková[1,2], Ali Hassan[1], Pavel Veverka[1], Kyo-Hoon Ahn[1], Karel Knížek[1], Denisa Kubániová[2], and Jaroslav Kohout[2] — [1]FZU - Institute of Physics, CAS, Praha, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University, Praha, Czech Republic

The Fourier transform of the magnetization response of a suspension of magnetic particles to a sinusoidal AC magnetic field provides so-called magnetic particle spectrum, i.e., a series of higher harmonics that originate in the non-linear $M(H)$ dependence. This characteristic is crucial for magnetic particle imaging (MPI), which is an emerging technique employing magnetic particles, typically in the superparamagnetic state, as exogeneous tracers for medical imaging. The magnetization dynamics of such tracers is governed by two distinct mechanisms, the Néel relaxation of magnetic moments and the Brownian rotation of whole particles. The present study is based on a series of hydrothermally prepared and thoroughly characterized (XRD, XRF, TEM, SQUID magnetometry) samples of $Co_{1-x}Ni_xFe_2O_4$ particles with x=0–0.5 and the mean crystallite size of 8–9 nm. Their silica-coated clusters, forming colloidally stable aqueous suspensions, were prepared, and MPI study was performed by means of an in-house built system (interchangeable coils impedance-matched to ∼10, 15, 25, 35, and 50 kHz; magnetic field up to 20 mT).

MA 37.2 Thu 15:15 H16

Nanoscale magnetic imaging with color centers in fiber-coupled diamond nanobeams — •Gesa Welker[1], Yufan Li[1], Richard Norte[2], and Toeno van der Sar[1] — [1]Delft University of Technology, Faculty of Applied Sciences, Lorentzweg 1, 2628 CJ Delft, the Netherlands — [2]Delft University of Technology, Faculty of Mechanical Engineering, Mekelweg 2, 2628 CD Delft, the Netherlands

Nitrogen vacancy centers (NV-centers) in diamond are powerful magnetic field sensors that are excited and read out optically. They are an established tool for imaging weak magnetic signatures of condensed matter samples such as skyrmions, spin waves or 2D magnetism [1]. We present a unique fiber-coupled approach to scanning probe magnetometry, where a diamond nanobeam with NV-centers at its apex is attached to a tapered optical fiber and scanned across a sample [2]. Fiber-coupling could enable a higher excitation and collection efficiency compared to traditional setups. It also simplifies measurements at low temperatures, because it eliminates the need for re-alignment of free-space optics. We demonstrate diamond nanobeam fabrication via quasi-isotropic etching and a robust nanobeam-fiber assembly using optical glue. With this setup, we performed a 2D scan of the magnetic stray field of a current-carrying wire with sub-micrometer resolution [3]. Our method is also promising for magnetic sensing with recently emerged color centers such as tin vacancy centers (SnV-centers) [4].

[1] Casola et al. Nat. Rev. Mater 3, 17088 (2018) [2] Y. Li et al. ACS Photonics 10, 1859-1865 (2023) [3] Y. Li, G. Welker et al., New J. Phys. 26, 103031 (2024) [4] T. Iwasaki et al. PRL 119, 253601 (2017)

MA 37.3 Thu 15:30 H16

Planar scanning probe microscopy enables nanoscale vector magnetic field imaging with nitrogen-vacancy centers — •Paul Weinbrenner[1,2], Patricia Klar[3], Christian Giese[3], Luis Flacke[4,5], Manuel Müller[4,5], Matthias Althammer[4,5], Stephan Geprägs[4], Rudolf Gross[4,5,6], and Friedemann Reinhard[1,2,6] — [1]Institute for Physics, University of Rostock, Rostock, Germany — [2]Department of Life, Light and Matter, University of Rostock, Rostock, Germany — [3]Fraunhofer Institute for Applied Solid State Physics, Freiburg, Germany — [4]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [5]Physics Department, Technical University of Munich, Garching, Germany — [6]Munich Center for Quantum Science and Technology, Munich, Germany

We present imaging of vector magnetic fields on the nanoscale using planar scanning probe microscopy with nitrogen-vacancy (NV) centers in diamond as magnetic field sensors. Instead of traditional tip-based scanning probes, we employ an extended bulk diamond doped with NV centers. Despite the probe's large lateral size, it can still be scanned in nanoscale proximity to a planar sample.

We perform repeated measurements with NV centers with different orientations to obtain a direct image of the three-dimensional vector magnetic field of magnetic vortices in a thin-film magnetic heterostructure. Our result opens the possibility of quantum sensing using multiple qubits within the same scanning probe, which can be used for entanglement-enhanced and massively parallel sensing schemes.

MA 37.4 Thu 15:45 H16

Nanostructure and Coercivity Mechanism of Single-Phase $\mathbf{Ce(Co_{0.8}Cu_{0.2})_{5.4}}$ — •Tatiana Smoliarova[1], András Kovács[2], Nikita Polin[3], Esmaeil Adabifiroozjaei[4], Shangbin Shen[4], Xinren Chen[3], Leopoldo Molina-Luna[4], Oliver Gutfleisch[4], Konstantin Skokov[4], Michael Farle[1], Baptiste Gault[3], and Rafal E. Dunin-Borkowski[2] — [1]Faculty of Physics and Center for Nanointegration, Universität Duisburg-Essen, Duisburg, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, Germany — [3]Max-Planck-Institut für Nachhaltige Materialien GmbH, Düsseldorf 40237, Germany — [4]Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

$CeCo_5$ rare-earth RCo_5 permanent magnets achieve high coercivity (H_C = 1 T) upon the addition of Cu up to 20%, making Ce-based magnets an abundant R-alternative to Sm-based magnets. Here, we report a study that employs TEM in conjunction with APT to investigate the $Ce(Co_{0.8}Cu_{0.2})_{5.4}$ magnet, prepared by induction melting followed by controlled heat treatment and water quenching. The process results in the formation of a cellular structure characterized by elongated along the c-axis, Cu-rich precipitates with a diameter of ∼ 5 nm and a length of ∼ 20 nm, surrounded by a Cu-poor matrix with a thickness of ∼ 10 nm. The alignment of the Cu-rich precipitates creates a preferential direction for zigzag-shaped domain walls, yielding effective pinning and H_C = 1 ± 0.05 T. Financial support by DFG, CRC/TRR 270 (project ID 405553726) is acknowledged.

MA 37.5 Thu 16:00 H16

Transport of Intensity Phase Retrieval in the Presence of Intensity Variations and Unknown Boundary Conditions — •Oleksandr Zaiets[1,2], Axel Lubk[1,2], Radmilla Kyrychenko[1], Daniel Wolf[1], Maximilian Wegner[1], Max Herzog[1], Moritz Winter[1,3,4], Praveen Vir[3], Johannes Schultz[1], Claudia Felser[3], and Bernd Büchner[1,2] — [1]Leibniz Institute for Solid State and Materials Research Dresden, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]Dresden Center for Nanoanalysis, cfaed, Technical University Dresden, Dresden, Germany

Transport of Intensity Equation (TIE) phase retrieval technique is widely applied in light, X-ray and electron optics to reconstruct, e.g., refractive indices, electric and magnetic fields in solids. The TIE method reconstructs the phase from two or three mutually slightly defocused microscopy images by solving an elliptic partial differential equation - the TIE. Here, we present a largely improved TIE reconstruction algorithm, which properly considers intensity variations as well as unknown boundary conditions in a finite difference implementation of the TIE. That largely removes reconstruction artifacts encountered in state-of-the-art Poisson solvers of the TIE, and hence significantly increases the applicability of the technique. We demonstrate the improved performance of the TIE reconstruction algorithm at a set of simulated and experimental image intensities arising from magnetic structures investigated in TEM.

MA 37.6 Thu 16:15 H16

Fast spectroscopic imaging using extreme ultraviolet interferometry — •Hannah C. Strauch[1], Fengling Zhang[2], Stefan Mathias[1], Thorsten Hohage[3], Stefan Witte[2,4], and G. S. Matthijs Jansen[1] — [1]University of Göttingen, 1st Institute of Physics, Göttingen, Germany — [2]Advanced Research Center for Nanolithography, Amsterdam, The Netherlands — [3]University of Göttingen, Institute of Numerical and Applied Mathematics, Göttingen, Germany — [4]Imaging Physics department, TU Delft, The Netherlands

Extreme ultraviolet (EUV) pulses generated by high harmonic gener-

ation (HHG) offer element-specificity in spectroscopic applications [1], and an excellent platform for nanoscale coherent diffractive imaging. Thus, the combination of time-resolved spectroscopy and microscopy using HHG light is highly promising, but it is only hardly explored due to the challenge of extracting full spectroscopic and microscopic information from measurements of reasonable duration.

We will present FTSH, an interferometric solution that combines Fourier-transform spectroscopy (FTS) and holography [2], employing a pair of phase-locked EUV pulses. This combination explicitly encodes the EUV spectral information in the diffraction pattern. Compared to traditional FTS, FTSH dramatically reduces the interferometric sampling requirements. This enables full spectroscopic images in less than two minutes and makes our approach particularly promising for femtosecond time-resolved spectroscopic imaging.

[1] Möller et al., Commun. Phys. 7, 74 (2024)
[2] Strauch et al., Opt. Express 32(16), 28644-28654 (2024)

MA 37.7 Thu 16:30 H16

Magnetic vector field imaging with single domain magnetooptical indicator films — •Michael Path and Jeffrey McCord — Institute for Materials Science, Kiel University, Germany

Robust and fast magnetic vector field imaging is essential for the characterization of, e.g., electronic systems. We present a magnetooptical method for quantitative and spatially resolved magnetic vector field imaging based on the use of magnetooptical indicator films. Simultaneous magnetooptical temperature extraction ensures temperature independent quantification of the magnetic field amplitude and angle. Yttrium-iron-garnet indicator films with in-plane and out-of-plane magnetic anisotropy can be used for this method. In both cases, a magnetic bias field is applied to bring the indicator film into a single-domain state along four different directions. By measuring the out-of-plane tilt of the magnetization with four images using magnetooptical microscopy, the local magnetic vector field distribution and the local temperature are obtained. As an example, the magnetic vector field distribution generated by the current of an integrated circuit is observed and compared with the calculations. The accuracy of this method is verified by means of relative and statistical error analysis.

15 min. break

MA 37.8 Thu 17:00 H16

Characterization of the periodic stray field along ferromagnetic domain textures in synthetic antiferromagnets — •R. J. Peña Román[1], S. Maity[1], F. Samad[2,3], A. Kákay[2], O. Hellwig[2,3], K. Kern[1,4], and A. Singha[5,1] — [1]Max Planck Institute for Solid State Research — [2]Institute of Ion Beam Physics and Material Research, Helmholtz-Zentrum Dresden-Rossendorf — [3]Insititute of Physics, Chemnitz University of Technology — [4]Institute de Physique, École Polytechnique Fédérale de Lausanne — [5]Institute of Solid State and Materials Physics, Dresden University of Technology,

Magnetic imaging of domains and domain walls (DWs) composing the texture of any magnetic material is a crucial step toward understanding their properties and finding solutions to tailor the material properties to achieve new technology-driven functionalities. Synthetic Antiferromagnets (SAFs) are particularly interesting due to their highly tunable properties since their magnetic texture can be controlled by adjusting the design parameters during fabrication. Here, we use diamond Nitrogen-Vacancy Scanning Probe Microscopy (NV-SPM) to investigate and characterize ferromagnetic domains with periodic stray fields in SAFs. The magnetic field in the sample is sensed by measuring the Zeeman splitting that it produces on the NV electron spin states, while the magnetic noise is detected due to its impact on the NV spin relaxation time. NV-SPM allows us to explore the sample properties quantitatively with high magnetic sensitivity and non-invasively at the nanoscale. It is essential to identify the nature of the DWs and engineer them for potential applications in magnonics or spintronics.

MA 37.9 Thu 17:15 H16

Investigation of charge-state stability in shallow NV centers with surface treatments — •Atharva Paranjape[1], Olga Shevtsova[1], Lisa Ebo[1], Toni Hache[1,2], Rainer Stöhr[2], Jörg Wrachtrup[2], and Aparajita Singha[1,3] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]3rd Institute of Physics and Research Center SCoPE, University of Stuttgart — [3]IFMP, Technical University of Dresden

Nitrogen-vacancy (NV) centers in diamond are optically active defects which can be used for precise measurement of magnetic fields. While near-surface NV centers can provide high spatial resolution in magnetic imaging, they also face charge-state instability, which is aggravated in in ultra-high-vacuum (UHV). Here we aim to develop surface-treatment methods to reduce charge-state instability of shallow ($<$ 10 nm from surface) NV centers in UHV conditions. We show that a TiO_2 coating using Atomic Layer Deposition (ALD) on nanostructured diamond stabilizes the charge state by modifying the local environment. These experiments are crucial for the development of a scanning NV magnetometer in UHV with a high spatial resolution.

MA 37.10 Thu 17:30 H16

Magnetic Force Microscopy: High Quality-Factor Two-Pass Mode — •Christopher Habenschaden[1], Sibylle Sievers[1], Alexander Klasen[2], Andrea Cerreta[2], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig — [2]Park Systems Europe GmbH, 68199 Mannheim

Magnetic Force Microscopy (MFM) is an effective technique for characterizing magnetic micro- and nanostructures, typically detecting interactions between a magnetically coated tip on an oscillating cantilever and the sample. MFM sensitivity is enhanced under vacuum conditions due to the higher cantilever quality factor (Q-factor), which significantly improves force sensitivity. However, the commonly used two-pass mode in MFM faces challenges under vacuum, as the high Q-factor can lead to tip crashing when surface forces overpower the restoring force during topography imaging.

Here, we present a novel approach for high-sensitivity vacuum MFM measurements while maintaining stable topography detection. Implemented on a Park Systems NX-Hivac AFM, this method modifies the two-pass mode to create a high Q-factor two-pass mode [1]. In the first pass, the cantilever's Q-factor is artificially lowered to ensure stable non-contact topography imaging. In the second pass, a phase-locked loop (PLL) measures the frequency shift, maintaining the maximum Q-factor for optimal sensitivity in magnetic field measurements. This approach prevents tip crashes during the first pass and eliminates non-linear phase response in the second pass, ensuring robust and precise measurements. [1] Rev. Sci. Instrum. 95, 113704 (2024).

MA 38: Magnetic Particles / Clusters & Biomagnetism

Time: Thursday 15:00–18:00 Location: H18

Invited Talk MA 38.1 Thu 15:00 H18

Liquid-mediated surface-surface interactions investigated by close-to-surface magnetic particle transport — •Rico Huhnstock, Yahya Shubbak, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Studying phenomena at the liquid-solid interface has tremendous significance for the physical, chemical, biological, and nanostructure sciences [1]. Experimental access to the underlying interactions is a nontrivial task, demonstrated for instance by the difficulties connected with performing atomic force microscopy measurements in liquids. In this talk, we propose a novel technique to inspect liquid-mediated surface-surface interactions based on guiding magnetic microparticles (MPs), surrounded by a quiescent fluid, along defined trajectories in the vicinity of a solid interface. The MP motion is induced by harnessing engineered magnetic stray field landscapes (MFLs) emerging from customized magnetic domain patterns imprinted into a topographically flat substrate. We will give an overview of the MFL fabrication process and discuss the influence of MP [2], liquid, and MFL [3] properties on the MP motion. Finally, we highlight, that the MP motion dynamics can be studied to identify changes in liquid-mediated DLVO interactions between surfaces of the MP and the underlying substrate.

[1] Chen *et al.* (2022), Advanced Materials Interfaces, 9(35):2201864.
[2] Huhnstock *et al.* (2021), Scientific Reports, 11(1):21794.
[3] Huhnstock *et al.* (2024), Small, 20(10):2305675.

MA 38.2 Thu 15:30 H18

Exploring iron nitrides: Insights from Mössbauer spectroscopy — •Lenka Kubíčková[1,2], Jaroslav Kohout[1], Tomáš Kmječ[1], Karel Knížek[2], Štefan Hricov[2,3], Ondřej Kaman[2], Yevhen Ablets[4], Robin Kidangan Paul[4], Stanislav Mráz[5], Jochen Schneider[5], Oliver Gutfleisch[4], and Imants Dirba[4] — [1]Faculty of Mathematics and Physics, Charles University, 180 00 Praha 8, Czechia — [2]FZU - Institute of Physics of the CAS, 162 00 Praha 6, Czechia — [3]Faculty of Science, Charles University, 128 00 Praha 2, Czechia — [4]Functional Materials, Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany — [5]Materials Chemistry, RWTH Aachen University, 52074 Aachen, Germany

Mössbauer spectroscopy, a powerful tool for probing the local electronic and magnetic properties of materials containing Mössbauer isotopes, will be employed to investigate selected examples of iron nitrides. First, we will show spectra of air-sensitive Fe_3N nanoparticles, which exhibit a high degree of structural disorder. Moreover, we will discuss formation of an oxide layer by their passivation, whose nature and extent is difficult to assess from other methods but is crucial for medical applications. Second, conversion-electron Mössbauer spectroscopy (CEMS) of $Fe_{4-x}Ge_xN$ (x = 0, 0.5 and 1) crystalline thin films allows us to determine not only the direction of magnetization in the film of the undoped phase, but also, together with the DFT calculations, position of the Ge atoms in the Fe_4N structure. Such local insights are valuable for designing and optimizing iron-based films, e.g., for their magnetic or thermoelectric applications.

MA 38.3 Thu 15:45 H18

Tunable magnetic behavior in $[CoFe_2O_4]_n$@Pt hybrid nanoparticles — •Joachim Landers[1], Moritz Raphael[2], Soma Salamon[1], Heiko Wende[1], and Annette Schmidt[2] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Department of Chemistry, Institute of Physical Chemistry, University of Cologne

$[CoFe_2O_4]_n$@Pt hybrid nanoparticles were prepared by growing monodisperse $CoFe_2O_4$ (CFO) nanocubes epitaxially on the corners of 6 nm cubic Fe/Co-doped Pt seeds. The hybrid particles display a defined configurational order, in which the CFO cubes cover the corner positions, allowing the formation with a variable number n of CFO cubes in reproducible geometries. Thereby, the hybrid particles represent a system of tunable intraparticular magnetic dipolar interaction, acting in superposition to the high cubic magnetocrystalline anisotropy of the CFO nanocubes. This competition creates a complex temperature-dependence of the shape of the magnetic hysteresis curves, dependent on the size and number of attached CFO nanocubes. In the future, this could facilitate the production of high-anisotropy and -magnetization hybrid particles of widely controllable magnetic behavior. To analyze the acting mechanisms and resulting magnetic properties, in-field Mössbauer spectroscopy and different magnetometry protocols were employed. The experimental observations are compared to micromagnetic simulations utilizing MuMax3. Funding by the DFG projects SCHM1747/16-1 and LA5175/1-1 is gratefully acknowledged.

MA 38.4 Thu 16:00 H18

Inductive Heating of ZnFe Nanoparticles — •Esra Uz[1], Yohei Fujita[2], Marina Spasova[1], Tatiana Smaliarova[1], Ivan Tarasov[1], Michael Farle[1], Yuko Ichiyanagi[2], and Ulf Wiedwald[1] — [1]Universität Duisburg Essen — [2]Yokohama National University

Hyperthermia is a novel medical treatment that uses magnetic fields in combination with specially designed magnetic nanoparticles for the non-invasive elimination of pathological cells. The ZnFe nanoparticles (6-19 nm) have been chemically synthesized and analyzed with a focus on applications in magnetic hyperthermia. The structure and morphology of the nanoparticles have been investigated using X-ray diffraction (XRD) and transmission electron microscopy (TEM). The results confirm the cubic spinel structure of the nanoparticles. Vibrating sample magnetometry (VSM) revealed a ferromagnetic character of the 19 nm particles with a saturation magnetization of 79.8 Am*m/kg. The smaller particles, however, have shown superparamagnetic behavior. For two distinct particle sizes, 11 nm and 19 nm, agarose gel electrophoresis was applied to experimentally measure the heating power in an alternating magnetic field (100-250 kHz, 0-50 mT). For the specific loss power (SLP), determined by calorimetry, our experiments show a maximum value of 71 W/g at a frequency of 247 kHz and B = 40 mT. These findings demonstrate that ZnFe nanoparticles are a promising candidate for applications in the context of magnetic hyperthermia.

MA 38.5 Thu 16:15 H18

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

Self-assembly allows for the aggregation of highly complex structures from simple components. Coupled with the highly tunable properties and susceptibility to external fields of magnetic particles this results in the potential to fashion systems with a plethora of applications. By decorating tubular particles with permanent magnets in specific patterns of up/down configuration we create different species of particles, whose behaviour is governed by a mix of attractive and repulsive interactions between individual magnets. This results in selective assembly between specific species, position and orientation. We show simulations of the interaction and dynamics of these particles with and without the influence of external fields and the surrounding medium.

MA 38.6 Thu 16:30 H18

Arranging dipoles on a ring to create homogenous fields — •Ingo Rehberg[1] and Peter Blümler[2] — [1]Experimental Physics, University of Bayreuth, D-95440 Bayreuth, Germany — [2]Institute of Physics, University of Mainz, 55128 Mainz, Germany

Homogeneous magnetic fields can be generated using appropriately arranged permanent magnets. Halbach rings serve as a prominent example of this approach [1], particularly effective when employing very long magnetic rods, often modelled as line dipoles. However, for shorter magnets, the optimal configuration of magnetic moments diverges from the traditional Halbach geometry [2]. In this talk, we present an experimental setup utilizing magnetic cubes and visualize the anticipated fields through an open-source animation of point dipole clusters [3].

[1] Peter Blümler and Helmut Soltner, Practical Concepts for Design, Construction and Application of Halbach Magnets in Magnetic Resonance. Appl. Magn. Reson. 54, 1701 (2023).
[2] Ingo Rehberg and Peter Blümler, submitted.
[3] Ingo Rehberg, From Concentric Halbach Rings to Tetraplex Cuts - Examine 540 Dipole Clusters with a Single Python Animation.

https://zenodo.org/records/11214206 (2024).

15 min. break

MA 38.7 Thu 17:00 H18

Quantum Mechanical Analysis of Complex Ferrimagnetic States in Iron Oxide Nanoparticles — •Valentína Berecová[1,2], Martin Friák[1], Naděžda Pizúrová[1], and Jana Pavlů[2] — [1]Inst. Phys. Mater., Czech Acad. Sci., Brno, Czech Republic — [2]Dept. Chem., Masaryk Uni., Brno, Czech Republic

Maghemite (γ-Fe_2O_3) is a biocompatible ferrimagnetic iron oxide that crystallizes in an inverse spinel lattice and can be viewed as magnetite (Fe_3O_4) with iron vacancies. Iron oxide nanoparticles related to maghemite have numerous applications in the biomedical field thanks to the combination of their magnetic properties, biocompatibility, low cytotoxicity and small size. Density functional theory calculations were employed to examine the local magnetic moments of individual atoms in two maghemite-related nanoparticles. Our calculations for the nanoparticles were inspired by bulk maghemite γ-Fe_2O_3, where tetrahedrally and octahedrally coordinated Fe sublattices have opposing orientations of local magnetic moments. Importantly, our results show that the nanoparticle surfaces create far more complex magnetic states compared to the magnetic ordering found in bulk. These complex magnetic states were described as "nested" ferrimagnetism, which is characterized by local magnetic moments of Fe atoms with mutually opposite orientations appearing even within each of the two (tetrahedral or octahedral) sublattices. Financial support from the Czech Academy of Sciences (*Praemium Academiae* of M.F.) is gratefully acknowledged. Computational resources were provided by the e-INFRA CZ project and IT4Innovations National Supercomputing Center.

MA 38.8 Thu 17:15 H18

Iron Nitride Magnetic Nanoparticles for Biomedical Applications — •Sayar Das[1], Yevhen Ablets[1], Lenka Kubíčková[2], Imants Dirba[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Germany — [2]FZU, Praha, Czech Republic

With the urgent need for advanced materials in healthcare, magnetic nanoparticles (MNPs) have emerged to be helpful in versatile biomedical applications such as Hyperthermia for cancer treatment, contrast agents for Magnetic resonance Imaging, drug delivery, and others. For such applications, MNPs must be small in size and have high saturation magnetization (M_s) for better performance. Typically, iron oxide nanoparticles are used as they are inexpensive, chemically stable, and show low toxicity. Owing to the superior properties of iron nitride phases, it is considered a promising candidate over traditionally used iron oxides. This study systematically investigates the synthesis and characterization of iron nitride nanoparticles for intended biomedical applications. MNPs are synthesized via the thermal decomposition method using $Fe(CO)_5$ as a precursor, where nitriding is realized with ammonia as a carrier gas. Key findings demonstrate that surfactant-free synthesis yields ε-Fe_3N nanoparticles with M_s up to 122 Am^2/kg and a mean particle size of 14 nm. Synthesis with surfactants results in nanoparticles with higher yields and enhanced M_s. Moreover, using pure hydrogen as a reducing agent during synthesis significantly improves magnetic properties, with room temperature M_s reaching 162 Am^2/kg at a particle size of 15 nm, which is the highest M_s in iron nitride nanoparticles prepared by wet chemical routes up to date.

MA 38.9 Thu 17:30 H18

Magnetophoretic distinction of differently surface-functionalized magnetic microparticles by transport in a quiescent liquid — •Yahya Shubbak, Katharina Eichhorn, Nikolai Weidt, Arne Vereijken, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Strasse 40, 34132 Kassel, Germany

Magnetic particles (MPs) transported in a quiescent liquid close to the surface of a substrate with a periodic magnetic domain pattern is a promising Lab-on-a-chip technology for the detection of MP-bound analytes, even when their size is negligible compared to the MP size. As a proof of principle, we show an all-optical method to distinguish single MPs of the same nominal size that are surface-functionalized with two different chemical groups. More specifically, MPs measuring 2 micrometer in diameter with a polymer coating with only carboxyl end groups (COOH) or a mixture of carboxyl and amino (NH2) groups, respectively, have been studied. Harnessing a variation of liquid-mediated surface interaction forces in our close-to-substrate MP transport scheme, the different MP surface potentials lead to different magnetophoretic mobilities. Accordingly, transport of these MPs in double-distilled water showed a remarkable difference in the average velocity where the COOH MPs were almost twice as fast as the NH2 counterparts. A thorough investigation using external magnetic field pulses of varying durations revealed a significant distinction between both MP species using only moderate flux densities of a few mT.

MA 38.10 Thu 17:45 H18

Structural, magnetic properties and induction heating behavior studies of Mn doped cupper ferrite nanopowders synthesized using co-precipitation method — •Mahmoud Ismail[1] and Diaa EL-Rahman Rayan[2,3] — [1]Biophysics Branch and Physics Department, Faculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt — [2]Central Metallurgical Research and Development Institute (CMRDI), P.O. Box: 87 Helwan, 11421, Egypt — [3]Department of Physics, Deraya University, New Minia, Minya, Egypt

In this research synthesizes nanocrystalline CuFe2O4 spinel structure using co-precipitation method. The pure copper ferrite is substituted by manganese MnxCu(1*x)Fe2O4 nanopowders (x from 0.0 to 1.0). XRD, HR-TEM, UV-visible-Spectrophotometer and vibrating sample magnetometer (VSM) are utilized in order to study the effect of variation of Mn2+ ions substitution and its impact on crystalline size, lattice parameters, microstructure and optical and magnetic properties of the formed nanopowders. Indeed, heating properties of the MnxCu(1-x)Fe2O4 nanoparticles in an alternating magnetic field at 160 kHz were estimated. The results reveal that the sonochemical method for polyethylene glycol (PEGylated) MnxCu(1-x)Fe2O4 nanoparticles with size 5 nm leads to pseudo-single domain with smallest loop area. Of note, it is clear that the specific heat rate SAR values were in the range from 104.5 to 302.0 W/g at different synthesis conditions. Finally, large SAR values are obtained within 10*15 min using low magnetic field, making Cu-Mn ferrite appropriate for hyperthermia treatment of cancer.

MA 39: Magnetic Thin Films

Time: Thursday 15:00–17:00 Location: H19

Invited Talk MA 39.1 Thu 15:00 H19
Voltage control of magnetism using hydrogen — •Markus Gössler — Chemnitz University of Technology, Chemnitz, Germany

Voltage-controlled magnetic properties have entered the research spotlight as they hold great potential for future spintronic and magnetic memory devices. The use of electrochemistry in voltage-controlled magnetism, dubbed magneto-ionics,[1] promises a superior energy efficiency compared to many conventional mechanisms. Here, we present a versatile magneto-ionic concept based on the hydrogen-loading into [Co/Pd]-based bilayers and multilayer structures with perpendicular anisotropy. We show that the magnetic properties of [Co/Pd] multilayers sensitively depend on the absolute hydrogen concentration in the material and that this concentration can be set electrochemically via the applied voltage.[2] Reversibility and switching speed, as the two main limitations towards practical magneto-ionic devices, can be improved by a targeted multilayer engineering, exploiting synergies with hydrogen electrocatalysis. Funding from DFG-499361641 and ERC-101125178 is acknowledged. [1] Nichterwitz et al. APL Mater. (2021) 030903; [2] Bischoff et al., Adv. Funct. Mater. (2024) 2405323

MA 39.2 Thu 15:30 H19
Magneto-ionic control of coercivity in electrodeposited Ni_xFe_{1-x} films — •Anna Ullrich[1], Florin L. Hambeck[1], Francesca Sgarbi Stabbellini[1,2], and Karin Leistner[1,2] — [1]Institute of Chemistry, TU Chemnitz — [2]Leibniz IFW Dresden

Magneto-ionic effects provide a promising route for low-voltage, nonvolatile control of magnetic materials, essential for next-generation, energy-efficient devices. Prior research has mainly focused on iron- or cobalt-based thin films and nanostructures.[1] So far only few works mention magneto-ionic effects for Ni-based alloys,[2,3] which are promising due to their unique magnetic properties. This study systematically investigates the magneto-ionic behavior of electrodeposited Ni_xFe_{1-x} films with thicknesses of (160 ± 30) nm as a material platform to enhance magneto-ionic functionality. Coercivities range from (0.4 ± 0.3) mT in $Ni_{80}Fe_{20}$ (permalloy) to (44.6 ± 0.6) mT in pure Fe, as measured by magneto-optical Kerr effect magnetometry. Magneto-ionic control upon electrolytic gating in 1 M KOH reveals a reduction of coercivity of up to 50 % (e.g., in $Ni_{70}Fe_{30}$) at -1.18 V versus Ag/AgCl. We discuss this modification in the context of a surface oxide reduction reaction, which can modify the domain wall pinning.[4] The observed effects highlight the potential of magneto-ionic Ni-Fe alloys, especially in thicker films, for sensing and actuation applications. [1] M. Nichterwitz et al., APL Mat. 2021, 9, 030903. [2] D. Murray et al., ACS Appl. Mater. Interf. 2021, 13, 38916. [3] De h-Ora et al., Zenodo 2021, doi:10.5281/zenodo.5769775. [4] J. Zehner et al., Adv. Electron. Mater. 2020, 6, 2000406.

MA 39.3 Thu 15:45 H19
Structural, magnetic and electrical properties of oxygen-deficient $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ thin films — Suqin He[1,2,3], •Oleg Petracic[1], Valeria Lauter[4], Lei Cao[1,5], Yunxia Zhou[5], Moritz Weber[2,3], Jürgen Schubert[6], Omar Concepción[6], Regina Dittmann[2,3], Rainer Waser[2,3], Thomas Brückel[1,3], and Felix Gunkel[2,3] — [1]JCNS-2, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany — [2]PGI-7, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany — [3]JARA-FIT, RWTH Aachen University, 52056 Aachen, Germany — [4]Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA — [5]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [6]PGI-9, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany

In $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ (LSCO) the gradual oxygen release triggers a phase transition from the initial ferromagnetic perovskite to an oxygen vacancy layered antiferromagnetic brownmillerite structure. We have studied LSCO thin films fabricated by pulsed laser deposition. In situ x-ray diffraction and polarized neutron diffraction reveals the topotactic phase transition of the LSCO thin films, which can be attributed to the release of oxygen and ultimately the transition to a coherently ordered BM phase. By comparing the magnetic and electronic properties of the sample at different oxygen deficient states, we demonstrate that the magnetic and electronic transitions are apart from the structural phase transition. S. He, O. Petracic, V. Lauter, L. Cao, Y. Zhou, M. L. Weber, J. Schubert, O. Concepción, R. Dittmann, R. Waser, T. Brückel, F. Gunkel, Adv. Funct. Mater. 2024, 34, 2313208.

MA 39.4 Thu 16:00 H19
Double Exchange Bias (EB) Effects in IrMn/CoFe/IrMn Systems — •Arne Vereijken, Varun Vanakalapu, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

The EB effect, characterized as an unidirectional anisotropy in a ferromagnet (FM) coupled to an antiferromagnet (AFM) through a shared interface[1], is utilized in Lab-on-Chip (LOC) systems[2], among other technologies. In LOC systems, it is combined with ion bombardment induced magnetic patterning (IBMP) to engineer magnetic stray field landscapes (MFLs)[2]. This work demonstrates that adding a second EB interface to the same FM adds a degree of freedom for tailoring MFLs, achieving stronger and steeper stray field gradients beneficial for LOC applications. Whether the two EBs are independent of each other, particularly when aligned parallel or at an angle, poses an intriguing question. Investigations using vibrating sample magnetometry and magneto-optical Kerr effect measurements and comparisons with advanced EB models tailored for polycrystalline systems and the specific measurement conditions[3], reveal that the EB strength in the employed Ir17Mn83/Co70Fe30/Ir17Mn83 systems slightly exceeds twice that of single EB systems. This is attributed to additive, mostly independent EBs, making the second EB a great candidate for refining MFL engineering. [1] Meiklejohn, W. H. et al. (1956). Phys. Rev. 102, 1413 [2] Holzinger, D. et al. (2015). ACS Nano 9 (7), 7323-7331 [3] Merkel, M. et al. (2022). Phys. Rev. B 106, 014403

MA 39.5 Thu 16:15 H19
Layer-resolved Vector Magnetometry using Generalized Magneto-optical Ellipsometry — •Carmen Martín Valderrama, Irene Prieto, Mikel Quintana, and Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain

For a detailed and quantitatively precise understanding of magnetic multilayers it is crucially important to determine their spatial magnetization configurations, particularly along the depth of their structures. Here, we demonstrate that it is possible to achieve layer-resolved vector magnetometry in nanoscale magnetic multilayer films by means of a single magneto-optical reflection experiment. We designed, fabricated, and measured a set of epitaxial ferromagnetic/nonmagnetic/ferromagnetic multilayer samples that exhibit in-plane uniaxial anisotropy and a tunable ferromagnetic interlayer coupling strength through the non-magnetic interlayer. By means of Generalized Magneto-optical Ellipsometry measurements, we obtain the entire optical reflection matrix R of a given sample for each applied field value, which allows us to monitor the field evolution of the magnetization vector for the two ferromagnetic layers independently. Hereby, we observe that the magnetization switching of one layer can trigger a discontinuous change of the magnetization in the second layer even for weak ferromagnetic interlayer coupling. Moreover, we reproduce the obtained behavior using a model of two coupled macrospins, which corroborates even the unexpected aspects of our experimental results and thus reinforces the sensitivity and reliability of our experimental layer-resolved vector magnetometry.

MA 39.6 Thu 16:30 H19
Ferrimagnetic moment arrangement in the Ti-doped Barium hexaferrite revealed by EMCD — •Hitoshi Makino[1], Devendra Singh Negi[2], Ján Rusz[3], Bernd Rellinghaus[1], and Darius Pohl[1] — [1]DCN, TUD Dresden University of Technology — [2]Indian Institute of Technology Jodhpur — [3]Uppsala University

Barium hexaferrite is a well-known ferrimagnetic complex oxide with good durability at high temperatures and in erosive environments. Previous research has indicated that Titanium 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) in the transmission electron microscope (TEM). We conducted EMCD experiments on three samples with different Titanium concentration ($BaFe_{12-x}Ti_xO_{19}$, x=0, 0.6, 1.0). We have deconvoluted the Fe L-edges as obtained from classical EMCD measurements into different oxidation states of iron

($Fe^{3+} \rightarrow Fe^{2+}$ generated by Titanium-substitution) to observe the changing of magnetic moment arrangement. High resolution EELS mapping revealed, that Ti^{4+} ion substitute mainly for the $4f_2$ site, an atomic site with parallel magnetic Fe moment. The EMCD signal of the Ti-rich sample ($BaFe_{12-x}Ti_xO_{19}$, x=1.0) indicate an antiparallel Fe^{2+} magnetic moment arrangement. This discrepancy will be discussed by using inelastic scattering simulations as well as DFT calculations. A detailed analysis of the underlying measurement errors and the involved limitations of the method will be presented.

MA 39.7 Thu 16:45 H19

Imaging Local Magnetic Moments with Atomic-Scale Electron Vortex Beams via EMCD in $BaFe_{11}TiO_{19}$ — •Darius Pohl[1], Hitoshi Makino[1], Bernd Rellinghaus[1], Rolf Erni[3], Devendra Singh Negi[5], Arthur Ernst[4], and Ján Rusz[2] — [1]DCN, TUD Dresden University of Technology, Dresden, Germany — [2]Uppsala University, Uppsala, Sweden — [3]Empa, Dübendorf, Switzerland — [4]JKU, Lenz, Austria — [5]Indian Institute of Technology Jodhpur

Electron magnetic circular dichroism (EMCD), the electron wave counterpart of X-ray magnetic circular dichroism (XMCD), enables element-specific measurement of spin and orbital magnetic moments with nanometer-scale resolution in transmission electron microscopy. Electron vortex beams (EVBs), recently discovered to carry quantized orbital angular momentum (OAM), are emerging as a promising tool for EMCD measurements, facilitating the analysis of magnetic properties in materials. Since EVBs can be tightly focused to sub-nanometer scales, this approach offers unprecedented potential for quantifying spin and orbital magnetic moments with exceptional spatial resolution. We employ specially designed condenser apertures to produce isolated, atomic-scale EVBs with user-defined OAM. As a proof-of-concept, we demonstrate vortex EMCD measurements on ferrimagnetic barium hexaferrite samples. For the first time, EVB-EMCD achieves the resolution necessary to resolve local ferrimagnetic order. The experimental findings are further corroborated by inelastic scattering simulations and density functional theory (DFT) calculations.

MA 40: Frustrated Magnets II

Time: Thursday 15:00–17:45 Location: H20

MA 40.1 Thu 15:00 H20

Magnetism of rare-earth A2Ir2O7 pyrochlore single crystals — •Filip Hájek[1], Daniel Staško[1], Kristina Vlášková[1], Jiří Kaštil[2], and Milan Klicpera[1] — [1]Charles University, Faculty of Mathematics and Physics, Department of Condensed Matter Physics,Ke Karlovu 5, 121 16 Prague 2, Czech Republic — [2]Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, 182 21 Prague 8, Czech Republic

The rare-earth A2Ir2O7 pyrochlore iridates form a heavily studied series of materials revealing a plethora of complex properties. Geometrically frustrated lattice, strong spin-orbit coupling comparable to the strength of electron correlations, or f-d exchange between rare-earth and iridium sites lead to, e.g., spin ice state [1], spin liquid [2], topological Mott insulator [3], axion insulator [4] or Weyl semimetal [4,5].

Among the A2Ir2O7 series, we focus on the previously less studied heavy rare-earth members, namely Ho2Ir2O7, Er2Ir2O7, and Lu2Ir2O7 single crystals. In these materials, the Ir sublattice magnetically orders above 100 K, inducing a transition from a (semi-)metal to an insulating state just below the ordering temperature. Our present work is aimed at the magnetism of newly synthesised A2Ir2O7 single crystals, which is discussed in the framework of antiferromagnetic domains and ferromagnetic domain interfaces.

[1] E. Lefrançois et al., Nat. Commun. 8, 209 (2017). [2] M. Kavai et al., Nat. Commun. 12, 1377 (2021). [3] Y. Otsuka et al., Sci. Rep. 11, 20270 (2021). [4] X. Wan et al., Phys. Rev. B 83, 205101 (2011). [5] X. Liu et al., Phys. Rev. Lett. 127, 277204 (2021).

MA 40.2 Thu 15:15 H20

Crystal growth and anisotropic magnetic properties of quasi-one-dimensional zigzag chain antiferromagnet: CaCoP2O7 — •Koushik Chakraborty[1], Aditi Agrawal[1], Isha Isha[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 f\"{u}r Festk\"{o}rperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

We report crucible free optical floating zone crystal growth and anisotropic magnetic properties of quasi-one-dimensional zigzag chain antiferromagnetic compound CaCoP2O7. In this quasi one-dimensional zigzag chain compound, magnetic lattice is formed by the Co2+ ions. We have characterized the single-crystals and analyzed them by using x-ray and Laue diffraction which reveals single-phase nature and the as grown single-crystals were found of ultra high quality. Magnetic susceptibility and magnetization measurements reveal antiferromagnetic ordering, evidenced by a pronounced downturn in susceptibility below the Neel temperature (TN =6.6 K) and negative Curie-Weiss temperatures (Theta-CW = -39.4 K). Further, we found clear signature of field-induced phase transition where on application of field AFM order is going to quantum paramagnetic state or maybe liquid phase (which needs further study to confirm).

MA 40.3 Thu 15:30 H20

Ultrasound Investigation of the Magnetic Phase Diagram of Rouaite $Cu_2(OH)_3NO_3$ — •Nikolai Pavlovskii[1], Anton Kulbakov[1], Aswathi M. Chakkingal[1], Justus Grumbach[1], Kaushick K. Parui[1], Ulrike Stockert[1], Maxim Avdeev[2,3], Ramender Kumar[4], Issei Niwata[4], Ellen Häussler[1], Roman Gumeniuk[5], Ross J. Stewart[6], Vladimir Pomjakushin[7], Sergey Granovsky[1], Mathias Doerr[1], Elena Hassinger[1], Sergei Zherlitsyn[8], Andreas Hauspurg[8], Yoshihiko Ihara[4], Darren C. Peets[1], and Dmytro Inosov[1] — [1]TU Dresden, Germany — [2]ANSTO, Sydney, Australia — [3]University of Sydney, Australia — [4]Hokkaido University, Japan — [5]TU Bergakademie Freiberg, Germany — [6]ISIS, United Kingdom — [7]PSI, Villigen, Switzerland — [8]HZDR, Dresden, Germany

Rouaite, $Cu_2(OH)_3NO_3$, is a low-dimensional quantum magnet with alternating ferromagnetic and antiferromagnetic spin chains. Its magnetic phase diagram has been studied using techniques such as magnetization and specific heat, revealing field-induced transitions. This work focuses on ultrasonic investigations, which uncover the coupling between magnetic and elastic properties. New results under hydrostatic pressure further demonstrate the tunability of the magnetic phases, highlighting the material's sensitivity to lattice modifications.

MA 40.4 Thu 15:45 H20

Emergent degeneracies in weakly coupled sawtooth chains: the case of bobkingite — •P. Peter Stavropoulos[1], Aleksandar Razpopov[1], Harrison LaBollita[2], Antia S. Botana[3], Michael R. Norman[4], and Roser Valentí[1] — [1]Goethe University, Frankfurt, Germany — [2]Flatiron Institute, New York, USA — [3]Arizona State University, Tempe, USA — [4]Argonne National Laboratory, Lemont, USA

The sawtooth chain, otherwise known as the Δ chain, has a long history as a minimal model of frustrated magnetism, serving as a realization of Shastry-Sutherland type solitons. While many material candidates, like delafossite, euchroit, atacamite, as well as fluorides, have been investigated, they leave much to be desired in the way of the ideal sawtooth chain. Here we present a proposal for revisiting a copper hydrate, bobkingite. Using ab initio methods we estimate the magnetic exchanges between copper sites, and find a spin model consisting of nearly ideal sawtooth chains, weakly coupled to its neighbors. We analyze the classical model of the coupled sawtooth chains, revealing emergent system size scaling degeneracies.

MA 40.5 Thu 16:00 H20

Trigonal distortion in the Kitaev candidate honeycomb magnet BaCo2(AsO4)2 — •M.M. Ferreira Carvalho[1,2], S. Roessler[1], Z. Hu[1], C.F. Chang[1], S. M. Valvidares[3], P. Gargiani[3], M. W. Haverkort[4], P. K. Mukharjee[5], P. Gegenwart[5], A. A. Tsirlin[6], and L.H. Tjeng[1] — [1]Max Planck Institute for Chemical Physics of Solids,Dresden — [2]Institute of Physics II, University of Cologne — [3]ALBA Synchrotron Light Source, Barcelona, Spain — [4]Institute for theoretical physics, Heidelberg University — [5]Lehrstuhl für Experimentalphysik VI, Universität Augsburg — [6]Felix Bloch Institute for Solid-State Physics, University of Leipzig

We conducted X-ray linear dichroism (XLD) and magnetic circular dichroism (XMCD) measurements on single crystals of the Kitaev candidate honeycomb lattice compound BaCo2(AsO4)2. The measurements employed the bulk sensitive inverse partial fluorescence yield technique, which is ideal for acquiring reliable X-ray absorption spectra from highly insulating samples , enabling precise quantitative analysis. Our experimental results revealed a significant LD signal, indicating strong trigonal distortion in the CoO6 octahedra in BaCo2(AsO4)2. We performed a detailed analysis of the experimental XAS and XMCD spectra using a full-multiplet cluster model within the configuration interaction approach. This analysis indicated that the hole density is predominantly localized in the a1g orbital. Through XMCD sum rules and theoretical calculations, we quantified both the spin and orbital magnetic moments.

MA 40.6 Thu 16:15 H20

Single crystal growth and anisotropic magnetic properties of honeycomb quantum antiferromagnets: Ba2A(PO4)2 (A = Ni, Co, Mn) — •Aditi Agrawal[1], Koushik Chakraborty[1], Isha Isha[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 f\"{u}r Festk\"{o}rperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

The magnetic framework (monoclinic-lattice) of the title compounds are composed of the honeycomb-lattice. We present a study of high-quality Ba2A(PO4)2 (A = Ni, Co, Mn) optically floating zone grown single crystals. Sharp anomalies were found in the thermodynamic measurements. The anomalies corresponding to the long-range-ordering (LRO) for all three single-crystals of honeycomb family were evident just below 5 K, reveals a long-range antiferromagnetic order in these single-crystalline samples. The dc-susceptibilities for inplane and out-of-plane magnetic fields are strongly anisotropic. Our Curie-Weiss analysis for Ni, Co, and Mn suggest strong orbital magnetism but it was found significant for Co2+ case, as it is known due to its Kramers' degeneracy nature. Further, on application of external magnetic field, all compound shows spin-flop transition at moderate field. However, Ba2Co(PO4)2 is interestingly driven to another ordered phase due to the field-induced transition via a field tuned quantum critical point which is expected close to the critical field of Bc ~ 6.5 T, as evident from our phase boundaries analysis on in B-T plane.

15 min. break

MA 40.7 Thu 16:45 H20

Modelling thermal transport in spiral magnets — •Margherita Parodi[1,2] and Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genova — [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 [1]. The thermal conductivity is found to be increasing with the diminishing twist angle, consistent with recent experiments [2]. The results pave the path to understanding magnetic thermal transport in other non-collinear magnets.

References: [1] A. Cepellotti and N. Marzari, Phys. Rev. X 6, 041013 (2016) [2] F. Sekiguchi et al., Nat. Commun. 13, 3212 (2022)

MA 40.8 Thu 17:00 H20

Pressure-tuning $Na_3Co_2SbO_6$ in the Kitaev Quantum Spin Liquid state — •Steven Gebel[1], Swarnamayee Mishra[1], Martin Sundermann[2], Marein Rahn[3], and Jochen Geck[1] — [1]Institute of Solid State and Materials Physics, Technische Universität Dresden, Haeckelstr. 3, 01069 Dresden, Germany — [2]PETRA III, Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [3]Center for Electronic Correlations and Magnetism, University of Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Honeycomb cobaltates with Co^{2+} ($3d^7$) ions have been proposed as materials that can host Kitaev's quantum spin liquid state (QSL). Specifically, $Na_3Co_2SbO_6$ has been predicted to exhibit a Kitaev QSL upon reduction of the trigonal ligand and crystal field splitting, which in turn might be possible via the elastic tuning of the lattice structure. This compound hosts edge-sharing CoO_6 octahedra and exhibits antiferromagnetic (AFM) zig-zag ordering below 7 K, reminiscent of other well-known QSL-candidate, α-$RuCl_3$. In this study, a combination of x-ray diffraction (XRD) and spectroscopy (NIXS) in diamond anvil cells (DACs) is used to establish the pressure dependence of the lattice structure and its effect on the electronic 3d-shell. The pressure dependent Co L-edge spectra are compared to multiplet calculations based on the structural data obtained from refinements of the XRD data. Combining elastic tuning of the lattice structure with XRD, Co L-edge spectra and core-level-spectroscopy simulations, is a very promising approach to confirm whether honeycomb cobaltates can be driven into the Kitaev QSL state.

MA 40.9 Thu 17:15 H20

Easy-axis Heisenberg model on the triangular lattice: from supersolid to gapped solid — •Martin Ulaga[1], Jure Kokalj[2,3], Takami Tohyama[4], and Peter Prelovšek[3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Faculty of Civil and Geodetic Engineering, University of Ljubljana, Ljubljana, Slovenia — [3]Department of Applied Physics, Tokyo University of Science, Tokyo, Japan — [4]Jožef Stefan Institute, Ljubljana, Slovenia

We investigate the easy-axis Heisenberg model on the triangular lattice by numerically studying excitations and the dynamical spin structure factor $S^{\mu\mu}(\mathbf{q},\omega)$. Results are analyzed within the supersolid scenario, characterized by the translation-symmetry-breaking parameter m_z and the supersolid off-diagonal order parameter $m_\perp$. We find very robust $m_z > 0$ in the whole easy-axis anisotropy regime $\alpha = J_\perp/J_z > 0$, even enhanced by the magnetic field $h > 0$. Results also support $m_\perp > 0$ for intermediate $\alpha < 1$ and $h > 0$. Still, at small $\alpha \lesssim 0.2$, relevant for recent experiments on the magnetic material $K_2Co(SeO_3)_2$, we find at $h = 0$ rather vanishing $m_\perp \sim 0$, consistent with numerical evidence of a finite magnon excitation gap

MA 40.10 Thu 17:30 H20

Localized Magnons in the Generalized Model of the Sawtooth Chain with Dzyaloshinskii-Moriya Interactions — •Vadim Ohanyan[1,2], Johannes Richter[3,4], Michael Sekania[5,6], Marcus Kollar[7], and Lucas Giambattista[7] — [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 — [3]Institut für Physik, Universität Magdeburg, P.O. Box 4120, D-39016 Magdeburg, Germany — [4]Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Straße 38, D-01187 Dresden, Germany — [5]Reichenzentrum, University of Augsburg, 86135 Augsburg, Germany — [6]Center for Condensed Matter Theory and Quantum Computations, Ilia State University, 0162, Tbilisi, Georgia — [7]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

We consider a generalized model of a spin-S sawtooth chain with three distinct exchange couplings and Dzyaloshinskii-Moriya (DM) interactions. The primary focus of our research is on various scenarios for magnonic flat-band formation and the corresponding properties of localized magnons. A general flat-band constraint is derived, which, due to the large number of parameters in the model, allows for a broad diversity of flat-band scenarios. We provide a detailed analysis of different solutions to the flat-band constraint, construct the associated localized magnon states, and study the properties of the one-magnon spectrum.

MA 41: Poster III

Time: Thursday 15:00–17:30 Location: P3

MA 41.1 Thu 15:00 P3

Electrical coupling of superparamagnetic tunnel junctions mediated by spin-transfer-torques — •Sinan Shu[1], Leo Schnitzspan[1,2], Mathias Kläui[1,2], and Gerhard Jakob[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55122 Mainz, Germany — [2]Max Planck Graduate Center Mainz, 55122 Mainz, Germany

Superparamagnetic tunnel junctions (SMTJs) have garnered significant interest as potential building blocks for neuromorphic computing due to their unique stochastic switching behavior, driven by thermal excitations. This work investigates the impact of electrical coupling on the stochastic dynamics of two in-plane magnetized SMTJs, combining experimental measurements with simulation studies. The coupling mechanism, enabled by spin-transfer torque, modulates the state probability of each SMTJ and influences their cross-correlation. By analyzing time-lagged cross-correlation, we determine the strength and direction of the coupling, revealing that high positive voltages induce the strongest coupling effect. Furthermore, we demonstrate voltage-tunable state probabilities and coupling control. Our findings highlight the emergence of similarity and dissimilarity effects in the state probability transfer curves of coupled SMTJs [1]. These results not only provide new insights into the interplay between spin-transfer torque and stochastic behavior but also underline the potential of SMTJs for applications in energy-efficient neuromorphic computing.

[1] L. Schnitzspan, M. Kläui, G. Jakob, Appl. Phys. Lett. 123, 232403 (2023).

MA 41.2 Thu 15:00 P3

Self-ordered colloid of surfactant-free hard ferromagnetic hexaferrite nanoplatelets: SAXS study — •Andrei Chumakov[1], Matthias Schwartzkopf[1], and Dirk Menzel[2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Technische Universität Braunschweig, Braunschweig

A novel type of stable magnetic colloids based on hard magnetic SrFe12O19 particles stabilized by electrical charge and dispersed in water was studied as an object of investigation. The colloidal single crystalline nanoparticles possess a plate-like shape with a mean lateral size of about 50 nm and thickness of 5 nm. Each particle carries a large permanent magnetic moment M and exhibits the highest intrinsic coercivity field HC values of about 0.4 T. The magnetic properties of a ferromagnetic colloid exhibit a minimal magnitude of the coercive force of the order of several Oe., which allows the change of particle's orientation easily under the action of an external magnetic field. Depending on the concentration, the nanoparticle can exist in the water media in the free 'gas', concentrated liquid crystal, and super concentrated 'solid' phases. Structural ordering in the concentrated magnetic colloids of nanoparticles was investigated by SAXS, SEM, and SQUID techniques. It was revealed that the self and externally-induced liquid crystal phase consists of stacks of magnetic nanoplatelets, which can be ordered to nematic or similar phases by the external magnetic field. Various methods for creating a concentrated liquid crystalline phase are considered. The features of interaction within alternating and constant magnetic fields were studied.

MA 41.3 Thu 15:00 P3

Current Induced Markov State Modeling with Skyrmions in Geometrical Confinements — Thomas Brian Winkler[1], Grischa Beneke[2], •Yuean Zhou[2], Johan Mentink[1], and Mathias Kläui[2] — [1]Radboud University, Institute for Molecules and Materials, Netherlands — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

Magnetic skyrmion in geometrical confinements have recently gained attention as a platform for neuromorphic computing for instance for Brownian Reservoir Computing [1, 2]. Despite significant progress with coarse-grained particle-based modeling of the stochastic dynamics of skyrmion [3], the interplay between stochasticity and device defects remains underexplored. Here, we extract the stochastic transitions of skyrmion between pinning sites using a simple Markov state framework. The resulting Markov state model enables system behavior prediction based on the effective energy landscape of the device. The time step for Markov state evolution is significantly faster than traditional simulations, which makes the system well-suited for leveraging the digital twin for predicting experimental outcomes and evaluating reservoir metrics. We also aim to implement energy-efficient Markov chain Monte Carlo algorithms in-materio.

[1] K. Raab et al., Nat. Commun. 13 (1), 6982 (2022)
[2] G. Beneke et al., Nat. Commun. 15 (1), 8103 (2024)
[3] T. B. Winkler et al., Appl. Phys. Lett. 124 (2), 022403 (2024)

MA 41.4 Thu 15:00 P3

Statistical Tests for True-Random-Number Generation with Superparamagnetic Tunnel Junctions — •Robin Tietgen[1], Leo Schnitzspan[1], Mathias Kläui[1,2], and Gerhard Jakob[1] — [1]Institute of Physics, Johannes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]Max Planck Graduate Center Mainz, Mainz 55122, Germany

Superparamagnetic tunnel junctions (SMTJs) change their magnetoresistance due to switching of the ferromagnetic free layer by thermal excitations. This property of the SMTJ can be utilized to design a random number generator (RNG). Evaluating RNG output signals with statistical tests such as the NIST Statistical Test Suite (NIST STS) [1] provides a measure for the randomness quality and therefore the quality of the RNG itself. This quality assessment is crucial when deciding whether a (pseudo) RNG is suitable for a specific application.

We show nanosecond timescale random telegraph noise (RTN) generated by SMTJs with encryption-quality randomness [2].

Fast and high quality RNGs facilitate upcoming unconventional computing techniques such as probabilistic computing and machine learning with noise-based learning algorithms. For these applications SMTJs are promising true RNGs, offering very fast RTN, ultra-low power consumption and excellent scalability.

[1] L. Bassham et al., NIST SP 800-22 Rev 1a (2010)
[2] L. Schnitzspan et al., Phys. Rev. Appl. **20**, 024002 (2023)

MA 41.5 Thu 15:00 P3

Local spin textures stabilised by geometrically-induced strain in 2D magnet Fe3GeTe2 — •Yuhan Sun[1], Max Birch[2], Simone Finizio[3,5], Lukas Powalla[1], Sayooj Satheesh[1], Eberhard Goering[1], Bettina Lotsch[1], Klaus Kern[1], Alexander Holleitner[4], Markus Weigand[5], Sebastian Wintz[5], and Marko Burghard[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]RIKEN Center for Emergent Matter Science, Wako 351-0198, Japan — [3]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Walter Schottky Institute and Physics Department, Technical University of Munich, 85748 Garching, Germany — [5]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Institut Nanospektroskopie, 12489 Berlin, Germany

Two-dimensional (2D) van der Waals ferromagnets have emerged as promising platforms for next-generation electronic and spintronic devices. However, achieving precise local control over magnetic domains and spin textures in these materials remains a significant challenge. Here, we demonstrate nanoscale manipulation of magnetism in the 2D ferromagnet Fe3GeTe2 (FGT) using geometrically-induced strain fields. Employing high-resolution scanning transmission X-ray microscopy, we directly visualize the impact of spatially varying uniaxial and shear strain profiles on the magnetic order of FGT sheets stamped onto nanopillar arrays. We observe that a strain of less than 0.5% locally elevates the Curie temperature of FGT by 10 K and stabilizes magnetic textures near the pillar corners.

MA 41.6 Thu 15:00 P3

Harnessing Van der Waals $CrPS_4$ and Surface Oxides for Nonmonotonic Exchange Bias in Fe_3GeTe_2 heterostructures — Aravind Puthirath Balan[1], Aditya Kumar[1], •Sadeed Hameed[1], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Centre for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, 7491 Trondheim, Norway

Due to their atomically flat interfaces, two-dimensional van der Waals (vdW) heterostructures serve as the ideal platform to study interfacial effects like exchange bias. In this study, exchange bias in a vdW heterostructure composed of the antiferromagnetic material $CrPS_4$ and the ferromagnetic material Fe_3GeTe_2 (FGT) with a naturally oxidized surface layer (O-FGT) is investigated by performing Anomalous Hall measurements. The observed exchange bias in this heterostructure exhibits a distinct and non-monotonic trend as a function of temperature below 140 K, which is attributed to the presence of ferrimagnetic Fe_3O_4 in the surface oxide layer whose induced exchange bias is modulated by the presence of the antiferromagnetic $CrPS_4$ layer. These findings highlight the multifaceted nature of exchange bias in van der Waals heterostructures and their potential for tailored manipulation and control of material properties.

[1] Puthirath Balan, A. et al., *ACS Nano* **18**, 8383-8391 (2024).

MA 41.7 Thu 15:00 P3

Exploring spin-lattice coupling in the Van-der-Waals Antiferromagnet FePS3 — •David Gutnikov, Fabian Mertens, David Mönkebüscher, Richard Leven, Sophie Bork, Umut Parlak, and Mirko Cinchetti — Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

Femtosecond laser pulses drive coherent ultrafast lattice dynamics and hybridized phonon-magnon interactions in the antiferromagnetic van der Waals semiconductor $FePS_3$. This study investigates the coupling between lattice vibrations and the magnetic system by examining the effects of excitation photon energy, sample temperature, and applied magnetic field on their dynamic interplay. Building on our previous findings [1], we conducted additional femtosecond white-light transient absorption measurements. In addition to the previously reported 3.2 THz coherent phonon mode — whose amplitude diminishes near the Néel temperature and vanishes in the paramagnetic phase — we confirmed its strong hybridization with a magnon under an external magnetic field, resulting in a coupled phonon-magnon mode that underscores the rich magneto-elastic interactions in this material. Beyond this, we identified a previously hidden phonon mode at 7.5 THz and shear oscillations around 20 GHz. These findings provide deeper insights into the spin-lattice coupling in $FePS_3$ and open new avenues for controlling THz magnonic dynamics in van der Waals antiferromagnets, with significant implications for advancing two-dimensional spintronic technologies.

[1] F. Mertens et al, Adv. Mater. 35, 2208355 (2023).

MA 41.8 Thu 15:00 P3

Pauli-Equation on Riemannian Manifolds — •Johann Posanski, Benjamin Schwager, and Jamal Berakdar — Marthin-Luther-Universität Halle-Wittenberg Institut für Physik

Describing the behavior of quantum systems under geometric constraints is of relevance both for research in the foundations of physics and in applied fields, such as the development of designer materials. Implementing the restriction of a quantum particle to a Riemannian manifold with an explicit confining potential provides an effective description of the reduced quantum dynamics and implies a potential-like term dependent on the geometric invariants of the space. Expanding this formalism to spin-1/2 particles, such as electrons, is an active area of research. In this work, the dynamics of non-relativistic spin-1/2 particles on a two-dimensional Riemannian manifold embedded in three-dimensional Euclidean space are derived. We find that the spin degree of freedom is unaffected by real-space constraints and the tangent Pauli equation fully describes the spinor dynamics when the whole structure is exposed to an electromagnetic field. The Zeeman energy is found to be unaffected by the confinement and remains gauge-invariant.

MA 41.9 Thu 15:00 P3

Interplay of valley and spin at the interface of $MnPS_3|WS_2$ heterostructure — •Purba Dutta and Nirmal Ganguli — Indian Institute of Science Education and Research Bhopal, MP, India

This work is focused on the proximity-induced effects of the $MnPS_3|WS_2$ heterostructure, particularly on the change of valley and spin splitting in some high symmetry points under the effect of SOC, exhibits a unique interplay of electronic, spintronic, and valleytronic properties due to its type-II band alignment and strong spin-orbit coupling. This heterostructure facilitates efficient charge separation, driven by the staggered band alignment, making it ideal for optoelectronic applications such as spin-polarized photodetectors. The magnetic proximity effect from MnPS* induces a tunable U-dependent Rashba spin-splitting at the interface, where the magnitude of the Rashba effect can be controlled by the on-site Coulomb interaction parameter (U). This coupling enables robust control over spin texture and spin-dependent transport. Moreover, circularly polarized light selectively excites carriers in the distinct valleys of WS_2, leading to enhanced valley polarization, further modulated by the magnetic exchange interaction from $MnPS_3$. This synergy between Rashba like effect-induced spin textures and valley polarization creates a platform for multifunctional optospintronic devices, offering avenues for tunable spin and valley-selective photodetection, spin filters. The Interplay of valley and spin at the interface of $MnPS_3|WS_2$ heterostructure heterostructure thus provides a versatile framework for advancing spintronic and valleytronic technologies.

MA 41.10 Thu 15:00 P3

Manipulating the sign of the interlayer exchange coupling — Nathan Walker[1] and •George Browne[2] — [1]The Open University, Milton Keynes, UK — [2]The Open University, Milton Keynes, UK

We demonstrate, using computer simulations and a non-equilibrium Greens function approach, that the sign of the out-of-equilibrium interlayer exchange coupling (ooeIEC) changes in the presence of an external bias. The system consists of a double barrier connected to an exchange coupled ferromagnetic tri-layer. We find a strongly nonlinear dependence of the spin current on voltage which results in the exchange coupled tri-layer switching between parallel and antiparallel configurations. Our results are in excellent agreement with earlier theoretical calculations, which predict an approximately 2π topological phase change of the (equilibrium) IEC. We believe that this could act as an energy efficient mechanism for magnetic switching which does not rely on spin-transfer torque (STT). There are potential applications to magnetoresistive random-access memory (MRAM), one of the principal contenders for a universal memory.

MA 41.11 Thu 15:00 P3

Enhancing the ultrafast THz emission in spintronic emitters via interface engineering — •Krishna Rani Sahoo[1], David Stein[2], Jannis Bensmann[1], Alexander Heise[2], Robert Schmidt[1], Steffen Michaelis de Vasconcellos[1], Manfred Albrecht[2], and Rudolf Bratschitsch[1] — [1]Institute of Physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]Institute of Physics, University of Augsburg, Universitätsstr. 1 Nord, 86159 Augsburg, Germany

Ultrafast THz spintronic emitters are based on the generation of THz radiation due to spin-to-charge conversion in magnetic (M) and non-magnetic (NM) bilayer stacks. The development of THz spintronic emitters focuses on enhancing their intensity, manipulating the THz signal, and exploring potential applications. To improve the performance of THz spintronic emitters, it is important to choose suitable material combinations (M/NM) and tailor the interface between the M and NM layers. In this study, we focus on engineering the interface of archetypical Fe/Pt THz spintronic emitters via irradiation with foreign atoms. Indeed, we find that the THz emission can be substantially increased by the implantation of ions at the Fe/Pt interface. Our result paves the way for efficient low-cost ultrafast THz spintronic emitters based on thin metal films.

MA 41.12 Thu 15:00 P3

Exploring the Coupling of Broadband Terahertz Dipoles to Metasurfaces — •Daniel Geyer[1], Rieke von Seggern[1], and Sascha Schäfer[1,2] — [1]Department of Physics, University of Regensburg, Regensburg, Germany — [2]Regensburg Center for Ultrafast Nanoscopy (RUN), Regensburg, Germany

Terahertz (THz) spectroscopy has emerged as a powerful tool for accessing low-energy excitations in matter, offering direct insights into fundamental material properties that govern electronic, thermal, and magnetic behaviors. In addition to large-area THz emission spectroscopy, a strongly confined THz source can be employed to locally map a material's response.

In this work, we explore the implementations of ultrathin THz sources coupled to plasmonic structures. Firstly, we demonstrate the microscale mapping of the coupling strength between resonator structures and localized terahertz dipoles on a patterned spintronic emitter [1]. In addition, we investigate the THz response of near-field-coupled topological metasurfaces based on the Su-Schrieffer-Heeger (SSH) model [2]. Lastly, we discuss the application of novel THz sources based on two-dimensional van-der-Waals materials.

[1] Rathje et al., ACS Photonics 10, 3435 (2023)
[2] Moritake et al., Nanophotonics 11, 2183 (2022)

MA 41.13 Thu 15:00 P3

Enhancement of spintronic terahertz frequency conversion efficiency via grating structures — •Hatice Nur Koyun[1], Ruslan Salikhov[1], Ciaran Fowley[1], Jürgen Lindner[1], Stephan Winnerl[1], Artur Erbe[1,2], Manfred Helm[1,2], Jürgen Fassbender[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

Spintronic terahertz (THz) frequency conversion in ferromagnet/heavy-metal heterostructures has the potential to develop spintronic THz emitters for the high-speed communication and data processing units. Applying the ultrafast demagnetization gives rise to spintronic THz frequency conversion with the appearance of THz second harmonic generation (TSHG). In the case of optimizing the potential for the spintronic THz frequency conversion, the limitations of low power efficiency can be overcome by using subwavelength structures such as an arrays of slits. In this study, we explore a pathway for efficiency enhancement by utilizing periodic gold arrays with a grating period smaller than the THz wavelength, which results in increased local THz fields. By varying the gap and width of the gold arrays, we find that the TSHG power efficiency increases with decreasing gap size of the grating. Furthermore, we demonstrate the potential for cavity enhancement, which can improve and control THz emission from spintronic THz emitters by placing a gold periodic array on the backside of a quartz glass substrate.

MA 41.14 Thu 15:00 P3

Terahertz field induced spin wave excitation in thin ferromagnetic metals — •Sergei Ovcharenko, Hoppe Wolfgang, Alexey Melnikov, and Georg Woltersdorf — Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, Halle 06120, Germany

In the novel concepts of charge-less data processing technologies spin waves are proposed as a carriers of data. One of the ways to excite and study the properties of spin waves on the picosecond time scale is to use the laser pulsed excitation and magneto optical probe. Optical excitation of spin waves in ferromagnetic metals has now been demonstrated using a short pulse of spin current leading to spin torque localized at the interfaces of a ferromagnetic and nonmagnetic metal, both with optical [1] and Terahertz (THz) excitation [2]. The use of short optical pulses in the THz spectral range to induce spin currents and generate spin-orbit torque (SOT) offers undeniable advantages: the SOT is linearly proportional to the THz field amplitude, the excitation and spin-wave frequencies can be well-matched, and minimal heating occurs due to the low excitation energy.

In our work, we demonstrate the optical excitation of spin waves in thin layers of ferromagnetic metals using the THz pump-optical probe technique, with a spintronic emitter as the source of THz radiation. We investigate the dependence of the excited modes on the thickness of the ferromagnetic metal. [1] Brandt Liane et al. Physical Review B 104.9 (2021): 094415. [2] Salikhov Ruslan et al. Nature Physics 19.4 (2023): 529-535.

MA 41.15 Thu 15:00 P3

Wide-field magnetic microscopy of two-dimensional magnetic materials with chiral overlayers — •Buddhika Hondamuni[1], Nir Bar-Gill[3], Angela Wittmann[2], and Dmitry Budker[1] — [1]Helmholtz Institute Mainz, Staudingerweg 18, 55128 Mainz, Germany — [2]Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [3]Hebrew University, Jerusellem, Israel

The objective is to investigate the interplay between magnetic domain structures (or skyrmions) in samples with Perpendicular Magnetic Anisotropy (PMA) and chiral polypeptides. Using Nitrogen Vacancy (NV) center-based continuous wave Optically Detected Magnetic Resonance (cw-ODMR) for stray magnetic field imaging in wide-field with a spatial resolution of $\sim 0.8\,\mu$m and magnetometric sensitivity up to sub-$\mu T/\sqrt{Hz}$ range within a field of view (FOV) of approximately $60 \times 60\,\mu m^2$, we study how chiral molecules influence magnetic textures including magnetic domain pinning and coercive force changes. The Chirality Induced Spin Selectivity (CISS) effect provides a unique mechanism for manipulating spin orientations through molecular symmetry, offering the potential to control and enhance magnetic domain behavior. This NV-based imaging technique paves the way for advanced magnetic materials and spintronic devices by enabling precise nanoscale analysis of magnetic textures. This work is supported by the Carl Zeiss Stiftung and conducted in collaboration with the Hebrew University of Jerusalem, Israel.

MA 41.16 Thu 15:00 P3

Investigating Magnetic Material Parameters Using Latent Measures — •Kübra Kalkan, Omer Fetai, Ross Knapman, Janine Graser, Atreya Majumdar, and Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Magnetic materials are vital in shaping modern technology [1]. Inhomogeneities, however, influence material properties and potentially degrade their performance.

In this study, we focus on quantifying how the local and global dynamic behaviour of the magnetic material is influenced by local material parameters. We apply latent inference methods [2,3] on simulated micromagnetic data to unveil the memory and stochastic properties of the magnetic material. A deep understanding of inhomogeneities is key to enhancing the properties of magnetic materials.

[1] O. Gutfleisch et al., Adv. Mater., 23, 821 (2011).
[2] D. R. Rodriges et al., iScience, 24, 3 (2021).
[3] I. Horenko et al., Comm. App. Math. and Comp. Sci., 16, 2 (2021)

MA 41.17 Thu 15:00 P3

Modeling the magneto-optical Kerr effect in three-dimensional magnetic microstructures — •Florian Ott, Christian Janzen, Bhavadip Rakholiya, Rico Huhnstock, and Arno Ehresmann — Institute of Physics, University of Kassel, Germany

Topographically-elevated magnetic microstructures with complex three-dimensional geometries are promising for the discovery and study of novel magnetic effects [1]. These microstructures can in principle be magnetically characterized using MOKE-based measurement devices intended for conventional planar material systems, like for instance a Kerr microscope [2]. However, the interpretation of data is not trivial, because the MOKE depends on the local reflection geometry [3]. Theortical calculations have been performed to characterize MOKE in magnetic multilayer systems with arbitrary surface normals. Further, simulations of simple optical setups have been performed to investigate the effects of the associated surface tilt on the optical path of light in the system. It has been found that additional contributions to the change in polarization of light are obtained by considering the image forming optics of the measurement device.

[1] Streubel, R., Tsymbal, E. Y., et. al. *J. Appl. Phys*, 129, 210902. (2021); [2] Janzen, C., Rakholiya, B. B., et. al. "Advancing Kerr-Microscopy Imaging of Three-Dimensional Magnetic Structures", *INTERMAG Short papers*, Rio de Janeiro, Brazil, pp. 1-2. (2024); [3] Soldatov, I., Kolesnikova, V., et. al. *IEEE Magnetics Letters*, 12, pp. 1-4 (2021)

MA 41.18 Thu 15:00 P3

Estimation of the exchange stiffness constant via domain wall widths using magnetic bilayers — •Florian Gossing, Michael Vogel, Dennis Seidler, and Jeffrey McCord — Nanoscale Magnetic Materials, Department of Materials Science, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

The exchange stiffness constant is a key parameter influencing the energy of (micro)magnetic systems. Magnetooptical measurements on compensating Néel walls of a FeCoSiB double layer structure are performed to determine the exchange stiffness constant. Parasitic magnetooptical effects such as the unavoidable magnetooptical gradient effect are removed by evaluating neighboring domain wall pairs of equal chirality. Corresponding modeled domain wall widths are compared with the experimentally determined widths, taking into account also the thickness dependent magnetooptical sensitivity function. Thus, the integral domain wall widths allow for an estimation of the exchange stiffness constant. The methodology is readily applicable to various thin film magnetic materials. The estimated exchange stiffness constants are compared with those obtained from ferromagnetic resonance measurements.

MA 41.19 Thu 15:00 P3

Observing static and dynamic magnetic textures with nanoscale resolution using NV magnetometry — •Ephraim Spindler[1], Philipp Schwenke[1], Duc Tran[2], Vitaliy Vasyuchka[1], 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, Mainz, Germany

Magnetization and stray field imaging is an essential tool for the characterisation of various magnetic materials and phenomena. Techniques such as Kerr microscopy, magnetic force microscopy or Lorentz transmission electron microscopy are well established and ideal for certain applications. However, their sensitivity, spatial resolution or invasiveness make them unsuitable for other applications. Scanning nitrogen vacancy (NV) magnetometry offers a solution with an excellent combination of high sensitivity and spatial resolution, without distorting the magnetic system of interest. The quantitative nature of the measurement principle allows the determination of the magnetic stray field at the sample surface, allowing the visualisation of magnetic textures even in materials with a very low saturation magnetization, such as canted antiferromagnets like hematite at room temperature. We employ NV magnetometry to study static magnetic textures in bulk hematite samples, and metallic multilayer stacks with perpendicular magnetic anisotropy. An outlook on NV center based spin wave spectroscopy is given.

MA 41.20 Thu 15:00 P3

Magneto-Optical Kerr microscopy of 3D non-planar non-curved magnetic thin films: simulation and experiment — •Christian Janzen, Florian Ott, Bhavadip Bharatbhai Rakholiya, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology,, University of Kassel, Germany

Extending magnetic thin film systems to the third dimension by deposition of magnetic materials onto defined templating structures results in a further degree of freedom to tailor magnetic properties by shape, topology, and chirality [1]. In this work, we present advances in characterizing such 3D systems utilizing conventional magneto-optical Kerr microscopy [2]. By investigating non-planar and non-curved 3D geometries experimentally as well as theoretically, geometric parameters can be manipulated in a systematic way. With this, the magnetic and non-magnetic contributions to the MOKE can be deconvolved. By studying the influence of geometrical parameters that effectively change the initial polarization of the incident light as well as the angle of incidence, we deepen the understanding of Kerr-microscopic signals measured on 3D curved nanomagnetic systems.

[1] G. Gubbiotti et al, "2025 Roadmap on 3D Nano-magnetism" J.Phys.: Condens. Matter in press, 2024

[2] C. Janzen, et al, "Advancing Kerr-Microscopy Imaging of Three-Dimensional Magnetic Structures", INTERMAG Short papers, Rio de Janeiro, Brazil, pp. 1-2, 2024

MA 41.21 Thu 15:00 P3

Exact exchange kernel for spin waves in the spin-polarized homogeneous electron gas — •Michael Neugum, Alexandre Borrameo Alcaïde, and Arno Schindlmayr — Universität Paderborn, Department Physik, 33095 Paderborn, Germany

Spin waves represent an important class of elementary excitations in magnetically ordered materials. *Ab initio* spin-wave calculations for real materials are often based on time-dependent density-functional theory. The crucial ingredient is the so-called exchange-correlation kernel, which incorporates the effects of the Coulomb interaction between the electrons. In general, the kernel is wavevector and frequency dependent, although its exact mathematical form is unknown. Practical implementations typically employ the adiabatic local-density approximation (ALDA), where the kernel is replaced by a simple constant. The results are generally in good qualitative agreement with experimental measurements but sometimes exhibit significant quantitative deviations. In this work, we implement the exact exchange kernel, which is based on a diagrammatic expansion to first order in the Coulomb interaction. We show results for the fully spin-polarized homogeneous electron gas in two and three dimensions. Overall, we observe a substantial discrepancy from the ALDA. In particular, the parabolic component of the dispersion, the spin-wave stiffness, is systematically lower for the exact exchange kernel. While the exact exchange kernel depends both on wavevector and frequency, the most significant effects are due to the wavevector dependence, whereas the frequency dependence may be neglected for practical purposes.

MA 41.22 Thu 15:00 P3

3D Trajectory Tracking of Remote-Controlled Superparamagnetic Particles in Liquid — •Nikolai Weidt, Rico Huhnstock, Yahya Shubbak, 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 develop Lab-on-a-chip systems, superparamagnetic particles (SPPs) can be surface-functionalized to specifically bind targeted analytes. A promising strategy for achieving analyte binding and transfer involves the directed transport of SPPs over magnetically stripe-patterned exchange bias layer systems. By precisely analyzing the three-dimensional trajectories of SPPs in this setup, we can detect events of analyte binding. To capture movement in the third dimension, we measure the defocusing of particles that exit the microscope's focal plane during transport steps. In this study, we quantify defocusing by calculating the Tenenbaum gradient (TG) for individual particles. This makes it possible to use a conventional light microscope combined with a piezo-controlled sample holder for 3D Trajectory tracking. Through a calibration process, we derive the z-coordinate of SPPs from the measured TG. The resulting 3D trajectories are validated through numerical simulations of SPP motion.

MA 41.23 Thu 15:00 P3

Experimental system of clinostat and Helmholtz cage for microgravity experiments in zero-value Earth magnetic field — Maciej Malczyk[1], Tomasz Blachowicz[1], and •Andrea Ehrmann[2] — [1]Institute of Physics - Center for Science and Education, Silesian University of Technology, 44-100 Gliwice, Poland — [2]Institute for Technical Energy Systems (ITES), Faculty of Engineering and Mathematics, Bielefeld University of Applied Sciences and Arts, 33619 Bielefeld, Germany

Plant cultivation under special conditions, in particular under different magnetic and gravitational conditions, is a relatively new research trend in connection with the development of space technologies. In addition to experiments in space, many studies are carried out under simulated microgravity with the help of a clinostat. Here, a self-designed and built system of coupled devices, a two-axis clinostat and a Helmholtz cage, is presented. The clinostat can, on average, cancel the effective gravitational field, while the correctly mounted Helmholtz cage can cancel the Earth's natural magnetic field [1]. Biological samples, such as plants or microalgae, can be placed in the central part of the system, in the special cultivation sphere. The system makes it possible to control the basic physical parameters and directly observe the growth process visually. The first experimental results of growth tests will be presented.

[1] M. Malczyk, T. Blachowicz, A. Ehrmann, Coupled system of dual-axis clinostat and Helmholtz cage for simulated microgravity experiments, Applied Sciences 14, 9517 (2024)

MA 41.24 Thu 15:00 P3

Finite-temperature DMRG calculations for big spin systems using matrix product states — •Lukas Horstmann and Jürgen Schnack — University of Bielefeld, Bielefeld, Germany

Doing finite-temperature calculations on bigger spin systems is often limited by the size of the Hilbert spaces being too large for algorithms such as exact diagonalisation or finite-temperature Lanczos. In order to work around this problem White proposed a method based on the Density Matrix Renormalization Group (DMRG) in the late 90th which allows the calculation of bigger systems by applying multiple local optimisation steps while truncating the size of the Hilbert space by a large amount without loosing too much information about the system. This method works, but it is slow. Therefore, the whole method was translated into a tensor representation using matrix product states where the full system and its operators are described by a tensor network which allows faster linear algebra calculations [1]. In this contribution we will expand this method to finite-temperature calculations using imaginity-time evolution with TenPy [2] to calculate thermodynamic properties for larger spin systems.

[1] Ulrich Schollwöck, doi: 10.1016/j.aop.2010.09.012

[2] Johannes Hauschild, Frank Pollmann, doi: 10.21468/SciPost-PhysLectNotes.5

MA 41.25 Thu 15:00 P3

Probing the magnetic anisotropy in mononuclear $4f$- and $5f$-complexes by high-field/high-frequency EPR — •J. Arneth, B. Beier, and R. Klingeler — Kirchhoff Institute for Physics, Heidelberg University, Germany

The quantitative experimental investigation of magnetic anisotropy in $4f$- and $5f$-compounds remains a challenging task as strong spin-orbit coupling and ligand field effects lead to complex electronic structures while magnetisation measurements often provide only scarce information. Here, we report high-frequency/high-field electron paramagnetic resonance spectroscopy (HF-EPR) studies on mononuclear

Er(III) [1,2], U(IV) and U(V) [3] molecular complexes, the former in various ligand coordinations. Our experimental data allow for the direct determination of zero field splittings (ZFS) and effective g-factors of the magnetic ground state and the low-energy excited states. The effect of the ligand fields as well as its relevance for the static and dynamic magnetic properties are discussed.

[1] Arneth et al., submitted
[2] Bazhenova et al., Molecules 26, 6908 (2021)
[3] Lichtenberger et al., J. Am. Chem. Soc. 138, 9033 (2016)

MA 41.26 Thu 15:00 P3

Tunable π-magnetism in carbon-based materials — •Nan Cao[1] and Adam Foster[1,2] — [1]Department of Applied Physics, Aalto University, Helsinki, Finland — [2]WPI Nano Life Science Institute, Kanazawa University, Kanazawa, Japan

Carbon-based π-magnetic structures have gained increasing interest for their promising role in spintronics, quantum computing, and advanced magnetic materials. Tailored functionalities in these structures are desired for their diverse applications. This study presents a systematic investigation of the tunability of these structures by incorporating different chemical linkages and doping with diverse heteroatoms. Using density functional theory (DFT) calculations, we explore how different linkage types - such as single, double bonds and aromatic, antiaromatic rings - and the introduction of dopants like nitrogen, boron, and sulfur affect the magnetic properties and electronic configurations of the π-conjugated carbon frameworks. Our results show that specific linkages can enhance magnetic coupling and stability, while heteroatom doping allows for precise control over magnetic moments and bandgap modulation. Furthermore, we identify optimal combinations of linkages and dopants that maximize tunability, offering pathways for designing customized π-magnetic materials with desired properties. These analyses deepen our understanding of structure-property relationships in carbon-based π-magnetic systems and provide a practical strategy for engineering next-generation magnetic materials with customized properties.

MA 41.27 Thu 15:00 P3

Exploring Data Representation Techniques in Deep Learning Models for Determining Ligand Field Parameters of Single-Molecule Magnets — •Preeti Tewatia, Zayan Ahsan Ali, Julius Mutschler, and Oliver Waldmann — Physikalisches Institut, Universitat Freiburg, D-79104 Freiburg, Germany

Single-Molecule Magnets (SMMs) present an exciting frontier in molecular electronics and quantum computing. According to ligand field theory, the single-ion magnetic anisotropies have in general to be characterized by 27 ligand field parameters. However, typical experimental data such as magnetic susceptibility as function of temperature measured on powder samples is pretty featureless, leading to an inverse problem where multiple parameter sets can equally describe the data. To address this challenge, a deep learning approach based on a Variational Autoencoder and an Invertible Neural Network hybrid architecture was employed. The model has been demonstrated before to be capable of handling the above inverse problem. This work focuses on improving the results of the model using data representation and augmentation techniques. For instance, augmenting the input data with simulated susceptibility curves which include experimental errors were found to enhance the robustness of the model with respect to these errors. This approach leads to better performance than conventional fitting techniques.

MA 41.28 Thu 15:00 P3

Inelastic Neutron Scattering on a Family of 3*d*-4*f* Mn_2Ln_2 Single Molecule Magnets — •Vishali Vishali[1], Julius Mutschler[1], Amal Bouraoui[1], Christopher E. Anson[2], Oliver Waldmann[1], and Annie K. Powell[2] — [1]Physikalisches Institut, Universitat Freiburg, D-79104 Freiburg, Germany — [2]Institut of Inorganic Chemistry, Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany

Recent studies in the Single Molecule Magnet (SMM) research area have increasingly focused on $4f$ ions, which offer enhanced magnetic anisotropy and angular momentum, offering new avenues for SMM research. However, the analysis of experimental data remains a challenge for $4f$ based SMMs due to overparametrization, and in the case of Inelastic Neutron Scattering (INS) due to low scattering intensities in pure $4f$ SMMs. A promising approach to overcome these challenges involves expanding the study to heterometallic SMMs incorporating both $3d$ and $4f$ ions. The inclusion of $3d$ ions can enhance INS intensities and improve the quality of INS data. This increases the amount of information on the $4f$ ion properties which can be drawn from the experiment. In this work, high quality INS data of Mn_2Ln_2-square complexes with Ln = Y, Tb, Ho, and Dy are presented. A comprehensive analysis and interpretation of the INS data as well as magnetic data is presented, providing deeper insights into the magnetic behavior of these systems.

MA 41.29 Thu 15:00 P3

Magnetic behavior of cuprate 1/2 spin quantum molecular magnet — •Jakub Šebesta and Dominik Legut — IT4Innovations, VŠB-TU Ostrava, 17.listopadu 2172/15, 708 00 Ostrava-Poruba, Czech Republic

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 confinements and the resulting unique physical properties. Apart from layer materials, molecular magnets are significant representatives. In this work, we are discussing an organometallic cuprate 1/2 spin quantum magnet bearing a 2D layered magnetic structure. Combining DFt calculation, an evaluation of magnetic exchange interactions with experimental results, we discuss the complex magnetic structures and the interplay of particular constituent elements in relation to the experimental observation.

MA 41.30 Thu 15:00 P3

Spin Seebeck effect in post-annealed $NiFe_2O_4$ thin films with varying lattice constants — •Fabian Meier, Julian Strassburger, Jan Biedinger, Tapas Samanta, Luana Caron, and Timo Kuschel — Bielefeld University, Germany

The longitudinal spin Seebeck effect (LSSE) in nickel ferrite (NFO) is a widely studied subject in the field of spin caloritronics [1]. Here, the dependence of the LSSE on the lattice constant is investigated in the ferrimagnetic insulator NFO. Two sample series have been fabricated by reactive DC magnetron sputter deposition [2], consisting of 45 nm thick NFO layers grown on $MgAl_2O_4$ substrates and post-annealed in an oxygen atmosphere at different temperatures ranging from 400 °C to 800 °C. Subsequently, the samples are capped by 3 nm of Pt for the spin current detection via the inverse spin Hall effect. The varying lattice constants of NFO, induced by the post-annealing, are analyzed with x-ray diffraction. The LSSE saturation voltage is determined by comparing the LSSE curves with magnetization measurements. Therewith, a linear contribution due to the ordinary Nernst effect in Pt is removed by adjusting the slope of the LSSE curve to match the magnetization curve in the saturation region. Afterwards, the averaged saturation values are determined as a function of the heat flux flowing through the sample. The spin Seebeck coefficient is calculated for each sample and the dependence on the post-annealing temperature, the lattice constants and the unit cell volume is examined.

[1] D. Meier et al., Nat. Commun. 6, 8211 (2015)
[2] C. Klewe et al., J. Appl. Phys. 115, 123903 (2014)

MA 41.31 Thu 15:00 P3

Sliding Through Topology: Unlocking the Tunable Hopf Index — Maria Azhar, •Sandra Chulliparambil Shaju, Ross Knapman, Alessandro Pignedoli, and Karin Everschor-Sitte — Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany

Recently, there has been growing interest in three-dimensional magnetic structures [1-3], especially regarding their intriguing topological properties and the calculation of their topological index [4]. In this study, we introduce a new approach to determine the Hopf index of magnetic textures, focusing on contributions from both the self-linking and cross-linking of flux tubes [5]. This alternative perspective provides deeper insight into the topological nature of magnetic textures, particularly those exhibiting non-integer topological indices, which we interpret as states of "mixed topology". We emphasize the critical role of the background magnetization in these three-dimensional textures, which influences whether the Hopf index is an integer or not. To illustrate these concepts, we present examples of three-dimensional magnetic textures within various backgrounds, including ferromagnetic, helical, and screw-dislocation configurations.

References:

[1] P. Sutcliffe, Phys. Rev. Lett. 118 (2017).
[2] F. Zheng, et al., Nature 623 (2023).
[3] M. Azhar, et al., Phys. Rev. Lett. 128 (2022).

[4] R. Knapman, et al., arXiv:2410.22058 (2024).
[5] M. Azhar, Sandra. C. Shaju, et al., arXiv:2411.06929 (2024).

MA 41.32 Thu 15:00 P3

Effective Geometric Model for a Magnetic Skyrmionium — •Finn Feldkamp, Alessandro Pignedoli, and Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

A Skyrmionium consists of a Skyrmion nested within another Skyrmion of opposite topological charge, rendering it a non-topological magnetic soliton. We use an effective geometric model to describe a Skyrmionium as a closed-loop domain wall in a thin magnetic film, extending approaches previously used for Skyrmions [1]. Our model not only provides insights into the stability of a Skyrmionium but also facilitates the analytical investigation of its excitation modes.

[1] D. R. Rodrigues, et al., PRB 97, 134414 (2018)

MA 41.33 Thu 15:00 P3

Inelastic neutron scattering in multi-Q structures in centrosymmetric systems — •Artem Nosenko and Dmitri Efremov — Leibniz Institute for Solid State and Materials Research, Dresden, Germany

In the current study we investigate centrosymmetric spin systems on a square lattice with spin frustration. We show that spin frustration leads to several single-Q helical structures and a double-Q structure.

We study the magnon spectra and calculate the dynamical structure factor for these magnetic structures. The results obtained show that inelastic neutron scattering can be a perfect tool for the identification of double-Q structures.

MA 41.34 Thu 15:00 P3

Gesture recognition with Brownian reservoir computing using geometrically confined skyrmion dynamics — •Grischa Beneke[1], Thomas Brian Winkler[1], Klaus Raab[1], Maarten A. Brems[1], Fabian Kammerbauer[1], Pascal Gerhards[2], Klaus Knobloch[2], Sachin Krishnia[1], Johan Mentink[3], and Mathias Kläui[1,4] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Infineon Technologies Dresden, Germany — [3]Radboud University, Institute for Molecules and Materials, the Netherlands — [4]Center for Quantum Spintronics, Norwegian University of Science and Technology, Norway

Physical reservoir computing utilizes complex physical systems' dynamics for efficient information processing, minimizing training and energy requirements. Magnetic skyrmions, topologically stabilized spin textures, offer promising reservoir computing capabilities through their stability, strong non-linear behaviour, and energy-efficient manipulation. We demonstrate a time-multiplexed skyrmion reservoir computing approach to overcome traditional limitations in temporal pattern recognition [1]. By aligning the reservoir's timescales with real-world data, our approach processes hand gestures captured by Range-Doppler radar. This method scales to the nanometer regime and demonstrates competitive or superior performance compared to energy-intensive software-based neural networks. Our hardware approach's key advantage is its ability to integrate sensor data in real-time without temporal rescaling, enabling numerous applications. [1] G. Beneke et al., Nat. Commun. 15, 8103 (2024).

MA 41.35 Thu 15:00 P3

Direct Manipulation of Topological Spin Textures with Magnetic Force Microscopy — •Minh Duc Tran[1], Elizabeth Martin Jefremovas[1], Mona Bhukta[1], Thomas Brian Winkler[1], Robert Frömter[1], Dennis Meier[2], and Mathias Kläui[1,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Department of Materials Science and Engineering, Norwegian University of Science and Technology (NTNU), 7034 Trondheim, Norway — [3]Center for Quantum Spintronics, Norwegian University of Science and Technology, 7491 Trondheim, Norway

We present a method to manipulate skyrmions in CoFeB-based multilayer stacks using magnetic force microscopy (MFM). By employing single-pass MFM scans, we eliminate disturbances from the initial topography mapping, allowing for direct control over the interaction with the complex spin textures [1]. Through precise tuning of the scan parameters such as lift height and write speed, we achieve localized transformations of the metastable skyrmion state into the energetically favored stripe domains [2]. Our findings offer a potential approach for generating more exotic spin textures by selectively creating/annihilating magnetic domains in a confined region [3].

[1] A. V. Ognev et al., ACS Nano 14, 11, 14960-14970 (2020).
[2] A. Casiraghi et al., Commun. Phys. 2, 145 (2019).
[3] E. M. Jefremovas et al., Appl. Phys. Lett. 125, 192402 (2024).

MA 41.36 Thu 15:00 P3

Minimizing pinning of magnetic skyrmions in multilayer thin films — •Alen John[1,2], Maria Andromachi Syskaki[1,2], Jürgen Langer[2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Singulus Technologies AG, 63796 Kahl am Main, Germany

Topological solitons, such as skyrmions, have attracted widespread attention due to their potential applications in unconventional computing and sensing. In this work, we present an optimization process for creating and stabilizing magnetic skyrmions with low pinning in multilayer thin films, using magnetron sputtering. We investigate Ta/CoFeB/MgO stacks with perpendicular magnetic anisotropy, systematically varying deposition parameters like sputter power and pressure to optimize skyrmion formation. Additionally, we introduce a Ta dusting layer between the ferromagnetic and MgO layers to fine-tune the magnetic anisotropy. This approach enables the fabrication of ultra-low pinning skyrmion samples that host room-temperature, thermally diffusing skyrmions[1], which are particularly promising for a range of emerging unconventional computing applications, including reservoir computing [2].

[1] J. Zázvorka et al., Nat. Nanotechnol. 14, 658 (2019) [2] G. Beneke et al., Nat. Commun. 15, 8103 (2024).

MA 41.37 Thu 15:00 P3

Exploring Topological Magnetism in Magnet-Superconductor Hybrid Systems — •Sayan Banik[1] and Ashis Nandy[2] — [1]National Institute of Science Education and Research, Jatni 752050, India — [2]National Institute of Science Education and Research, Jatni 752050, India

In this study, we engineer magnet-superconductor hybrids (MSHs) by placing 3d transition metals (TM) on the surface of the s-wave superconductor (SC), Nb. By employing a systematic search approach, we select a few members within this MSH family that exhibit magnetism according to Hund's first rule, depending on two different superconducting surfaces. Interestingly, the weak spin-orbit coupling at these interfaces causes the magnetic behavior to differ from what Hund's rule predicts.

By employing detailed ab initio electronic structure calculations followed by spin-lattice simulations, we further explored these materials, discovering many complex and unusual spin textures. For example, Cr/Nb(110) and Mn/Nb(110) are found to exhibit antiferromagnetic spin spiral (AFM-SS) ground states. In contrast, Fe/Nb(001) exhibits antiferromagnetic (AFM) order, while Cr/Nb(001) displays a magnetic state with an AFM chain along the x-direction and a spin spiral modulation along the y-direction. The strain affects these magnetic ground states, finding that the AFM-SS of Mn/Nb(110) changes to AFM order when in-plane strain is applied.

We find a hexagonal skyrmion lattice by covering the top surface of the TM-SC with two layers of heavy metal.

MA 41.38 Thu 15:00 P3

Resonant X-ray Elastic Scattering of Chiral Magnets — Sina Mehboodi[1,3], •Mathew James[4], Victor Ukleev[2], Chen Luo[2], Florin Radu[2], Christian H Back[1,3], and Aisha Aqeel[1,3,4] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [4]University of Augsburg, Augsburg, Germany

Resonant Elastic X-ray Scattering (REXS) is an element specific synchrotron X-ray technique that combines diffraction and spectroscopy. It can be used to study complex magnetic materials and provides a sensitive probe for the spatial modulation of spin configuration. This technique has been used to explore a chiral magnet Cu_2OSeO_3. Cu_2OSeO_3 is a unique magnetic insulator that exhibits a complex spin configuration, including helices, conical spirals, and skyrmions. We studied the skyrmion phase and the tilted cone phase of the high-quality single crystal Cu_2OSeO_3 at low temperature [1] using the REXS technique, which occurs when the energy of the incident X-ray photon is matched near the absorption edge of a magnetic element, in this case Cu. We carried out all the experiments by tuning the photon energy to the L_3

edge of Cu. We can directly observe the magnetic diffraction pattern caused by the magnetic arrangement of Cu^{2+} ions in different phases of Cu_2OSeO_3.

[1] A. Aqeel et al., Physical Review Letters 126, 017202 (2021)

MA 41.39 Thu 15:00 P3

Topological Phase Transition and Topological Protection in Van Der Waals Ferromagnet Fe3GeTe2 Thin Flake — •Sourav Chowdhury[1], Michael Schneider[2], Soumyaranjan Dash[3], Christopher Klose[2], Chithra Sharma[4,5], Lisa-Marie Kern[2], Tim Butcher[2], Josefin Fuchs[2], Santanu Pakhira[6], Amir-Abbas Haghighirad[6], Sujit Das[7], Sanjeev Kumar[3], Bastian Pfau[2], and Moritz Hoesch[1] — [1]Deutsches Elektronen-Synchrotron, Hamburg, Germany — [2]Max-Born-Institut, Berlin, Germany — [3]Indian Institute of Science Education and Research, Mohali, India — [4]University of Hamburg, Hamburg, Germany — [5]Christian-Albrechts-University Kiel, Kiel, Germany — [6]Karlsruhe Institute of Technology, Karlsruhe, Germany — [7]Indian Institute of Science, Bengaluru, India

Topological spin textures in 2D van der Waals (vdW) magnets are increasingly sought for high-performance spintronic devices, presenting transformative potential for ultra-dense data storage, energy-efficient operation, and advanced data processing capabilities [1]. We image various topological spin textures within a vdW ferromagnet Fe3GeTe2 thin flake. We observed topological protection versus non-protection behavior at close-to versus well-below the ferromagnetic transition temperature. Monte-Carlo calculation suggests that the switching among distinct topological spin textures can be achieved with the interplay between the Rashba spin-orbit coupling and the uniaxial-magnetic-anisotropy. [1] K. Chang et al. Science 2016, 353, 274.

MA 41.40 Thu 15:00 P3

Thiele model computer simulations of magnetic skyrmions — •Anna Endres, Simon M. Fröhlich, Jan Rothörl, Maarten A. Brems, Raphael Gruber, Leonie-C. Dany, Tobias Sparmann, Mathias Kläui, and Peter Virnau — Institute of Physics, Johannes Gutenberg University Mainz, Germany

Magnetic skyrmions can be approximated as rigid particles in 2D in the framework of the Thiele model [1]. This coarse-grained approach in principle enables simulations of hundreds or even thousands of skyrmions on experimentally relevant time and length scales [2]. Skyrmion interactions and pinning landscapes can be inferred directly from corresponding experiments [3][4]. Recently, we have also developed methods to match time and force scales of simulations with experiments, enabling quantitative and predictive simulations. In this poster we summarize our results and provide details on our modelling approach [5].

[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)
[5] M. A. Brems et al., in preparation

MA 41.41 Thu 15:00 P3

Effective field theory of the Quantum Skyrmion Hall Effect — •Vinay Patil[1,2], Rafael Flores-Calderòn[1,2], and Ashley M. Cook[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187, Dresden, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Strasse 38, 01187, Dresden, Germany

Motivated by phenomenology of myriad recently-identified topologically non-trivial phases of matter, we introduce effective field theories (EFTs) for the quantum skyrmion Hall effect (QSkHE). We employ a single, unifying generalisation for this purpose: in essence, a lowest Landau level projection defining a non-commutative, fuzzy sphere with position coordinates proportional to SU(2) generators of matrix representation size N, may host an intrinsically 2+1 dimensional, topologically non-trivial many-body state for small N as well as large N . That is, isospin degrees of freedom associated with a matrix Lie algebra with N * N generators potentially encode some finite number of spatial dimensions for N > 1, where isospin has previously been treated as a label. This statement extends to more general p-branes subjected to severe fuzzification as well as membranes. As a consequence of this generalisation, systems with d cartesian spatial coordinates and isospin degrees of freedom encoding an additional δ fuzzy coset space coordinates can realise topologically non-trivial states of intrinsic dimensionality up to d+δ+1. We furthermore generalise these EFTs to space manifolds with local product structure exploiting the dimensional hierarchy of (fuzzy) spheres.

MA 41.42 Thu 15:00 P3

A C*-algebraic approach to orbital magnetization in skyrmion crystals and finite magnetic fields — •Pascal Prass[1], Duco van Straten[2], and Yuriy Mokrousov[1,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Institute of Mathematics, Johannes Gutenberg University Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany

Skyrmion crystals can induce orbital magnetization even in the absence of spin-orbit coupling [1]. This depends on the skyrmion density determining the strength of the emergent magnetic field. As the length scale of a skyrmion crystal approaches the lattice constant of its host material, topological gaps may open in the associated electronic system similar to the formation of Landau levels. However, the smooth texture approximation for the emergent magnetic field is no longer satisfied [2]. Therefore, we utilize a fully algebraic framework to describe a tight-binding system coupled to a skyrmion crystal, that allows us to numerically evaluate topological gap invariants [3] and orbital magnetization even in the presence of finite magnetic flux. This way, we can describe the dependence of the orbital magnetization on the magnetic field for different skyrmion densities. In the appropriate limit, this approach coincides with the expression from the modern theory of orbital magnetization [4]. [1] Göbel et al. Phys. Rev. B **99**, 060406(R) (2019). [2] Lux et al. Phys. Rev. Res. **6**, 013102 (2024). [3] Prass et al. SciPost Phys. Core, *in press* (2024). [4] Schulz-Baldes et al. Commun. Math. Phys. **319**, 649-681 (2013)

MA 41.43 Thu 15:00 P3

Stoichiometry-control of topological ground states in the Kondo lattice CeAlGe — •Soohyeon Shin[1,2], Igor Plokhikh[2], Jonathan White[2], Vladimir Pomjakushin[2], Pascal Puphal[3], and Ekaterina Pomjakushina[2] — [1]Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Jülich, Lichtenbergstrasse 1, D-85747 Garching, Germany — [2]PSI Center for Neutron and Muon Sciences, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [3]Max-Planck-Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

CeAlGe crystalises in tetragonal structure I41md, where the spatial-inversion symmetry is broken, and is expected to exhibit Weyl fermions near a Fermi surface that becomes more stable by broken time-reversal symmetry. CeAlGe grown by the flux method, off-stoichiometric case, exhibits a commensurate antiferromagnetic order below T = 5.1 K, whereas the crystal grown by floating-zone methods with 30 bar of Ar gas (p=30 bar), stoichiometric case, exhibits an incommensurate order below T = 4.4 K in which topological Hall effects are induced by external magnetic fields applied in the c-axis. In this presentation, we show the newly synthesised CeAlGe using the same floating-zone method but with lower Ar pressure of p=5 bar. Our neutron diffraction and electrical Hall transport experiments revealed that the topological magnetism remains with shorter periodicity. Given all experimental results of flux-grown and two floating-zone-grown CeAlGe, we will discuss the mechanism of topological magnetism with respect to the Kondo coupling strength.

MA 41.44 Thu 15:00 P3

Quasiparticle interference in an altermagnetic tight-binding model — •Eric Petermann, Kristian Maeland, and Björn Trauzettel — Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany

Altermagnets constitute novel magnetic systems characterized by compensated magnetic ordering and momentum-dependent spin splitting without net magnetization. We employ tight-binding models to analyze quasiparticle interference (QPI) patterns in altermagnetic lattices. In the presence of impurities, scattering processes give rise to spatial modulations of charge and spin densities emerging from the interference of quasiparticles. This interference results in QPI patterns near those impurities. We relate the QPI patterns with the type of altermagnetic order.

MA 41.45 Thu 15:00 P3

Spin-Orbit Torque in RuO_2|Py multilayer systems — •Niklas Schmolka, Maik Gaerner, Jan Schmalhorst, and Günter Reiss — Bielefeld University, Germany

Spin torques like the Spin-Orbit torque (SOT) offer fast and energy efficient data writing techniques in magnetic memory devices (MRAM). As a new class of materials, Altermagnets, like RuO_2, are able to generate a current induced SOT while possessing zero net magnetization. As such, Altermagnets offer multiple advantages compared to existing MRAM devices based on Ferromagnets like higher stability against external magnetic fields and THz Switching [1][2].
Here, we use the harmonic Hall measurement technique to determine the Spin Hall Angle (SHA) in RuO_2|Py multilayer system via the Harmonic Response Modell [3]. To accurately determine the SHA we first characterize our samples using X-ray diffraction, X-ray reflection, Alternating Gradient Magnetometry and measure the magnetization and the Anomalous Hall Effect. We compare our experimental results to the existing literature and reflect on the influence of the crystal structure on the generated spin current [4].

[1] A. Bose et al., Nat. Electron. 5 267 (2022)
[2] S. Schlauderer et al., Nature 569 383 (2019)
[3] M. Meinert et al., Phys. Rev. Applied 14 064011 (2020)
[4] H.Bai et al., Phys. Rev. Lett. 128 197202 (2022)

MA 41.46 Thu 15:00 P3

Growth of altermagnetic MnTe thin films — •Lena Hirnet, Marco Dittmar, Hannes Haberkamm, Maximilian Ünzelmann, and Friedrich Reinert — Exp. Physik VII and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Germany

Recently, altermagnets have attracted great attention combining antiferromagnetic spin alignment in real space with a momentum-dependent spin polarization of the electronic states in the band structure. One of the proposed altermagnet work horse materials is MnTe [1,2]. Here, we investigate the epitaxial growth of MnTe on different substrates ranging from trivial band insulators to topological van der Waals metals with spin-momentum-locked surface states. The atomic and electronic structure of these films is studied employing low-energy electron- and x-ray diffraction as well as soft x-ray angle-resolved photoemission spectroscopy, respectively.

[1] L. Šmejkal *et al.*, Phys. Rev. X **12**, 031042 (2022)
[2] J. Krempaský *et al.*, *Nature* **626**, 517-522 (2024)

MA 41.47 Thu 15:00 P3

Interplay and Robustness of Dual-sublattice Altermagnetic Ordering in $Er_2Ru_2O_7$ — •Michele Reticcioli[1], Paolo Radaelli[2], and Alessandro Stroppa[1] — [1]CNR-SPIN L'Aquila, Italy — [2]University of Oxford, United Kingdom

Altermagnets, a novel class of magnetic materials, bridge the gap between conventional antiferromagnets and ferromagnets by hosting spin-split electronic structures without net magnetization. These materials hold promise for spintronic applications due to their unique symmetry-driven properties. In this work, we explore altermagnetism in the oxide semiconductor $Er_2Ru_2O_7$, which exhibits a rare double altermagnetic ordering arising from the Er and Ru magnetic sublattices. Using density functional theory, we investigate the interplay between the two sublattices, giving rise to two Neel vector order parameters, revealing a complex interplay that shapes the material's magnetic behavior. Furthermore, we analyze the impact of doping on the magnetic properties. Our findings show that while the Er sublattice demonstrates remarkable robustness against p-doping, the Ru sublattice undergoes significant changes. Notably, local substitution of oxygen atoms with nitrogen dopants leads to a drastic alteration in the Ru-sublattice magnetic ordering. These results shed light on altermagnetism in oxides, particularly on the interplay between sublattices and the sensitivity to doping, opening new avenues for tailoring magnetic properties in altermagnets for technological applications.

MA 42: Members' Assembly

Time: Thursday 18:00–19:00 Location: H20

All members of the Magnetism Division are invited to participate.

MA 43: Skyrmions III / Non-Skyrmionic Magnetic Textures II

Time: Friday 9:30–13:15 Location: H16

MA 43.1 Fri 9:30 H16

All-Optical Control of Bubble and Skyrmion Breathing — •Tim Titze[1], Sabri Koraltan[2], Timo Schmidt[3], Dieter Suess[2], Manfred Albrecht[3], Stefan Mathias[1], and Daniel Steil[1] — [1]I. Physikalisches Insitut, University of Göttingen — [2]Physics of Functional Materials, Faculty of Physics, University of Vienna — [3]Institute of Physics, University of Augsburg

Topologically protected magnetic skyrmions promise tremendous potential for innovative applications, such as unconventional computing schemes. Deterministic control of the dynamics of such spin objects is one key ingredient for future data processing devices. Using ultrafast Kerr spectroscopy, we investigate the spin dynamics of ferrimagnetic $[Fe(0.35\,nm)/Gd(0.40\,nm)]_{160}$ multilayers hosting a dense bubble/skyrmion (BSK) lattice at ambient temperature [1, 2]. Ultrafast laser excitation of the BSK lattice leads to coherent spin dynamics in the form of BSK breathing [3]. By tuning the time delay between excitations in a dual pulse excitation scheme we demonstrate optical control of the breathing dynamics of the BSK lattice in amplitude and phase [4]. This fast and reversible technique presents a promising pathway towards future BSK-based spintronic and magnonic devices.

[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.*, Adv. Funct. Mater. **34**, 2313619 (2024)
[4] T. Titze *et al.*, Phys. Rev. Lett. **133**, 156701 (2024)

MA 43.2 Fri 9:45 H16

Spiral multiferroics as a natural skyrmion racetrack — •Luca Maranzana[1,2], Maxim Mostovoy[3], Naoto Nagaosa[4], and Sergey Artyukhin[1] — [1]Quantum Materials Theory, Italian Institute of Technology, Via Morego 30, Genoa, Italy — [2]Department of Physics, University of Genoa, Via Dodecaneso 33, Genoa, Italy — [3]Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 3, 9747 AG Groningen, Netherlands — [4]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan

Magnetic skyrmions are localized spin textures with a nontrivial topology. This property ensures excellent stability even at nanometer length scales, establishing skyrmions as promising information carriers in magnetic storage and processing devices. Still, their fate in a wide variety of magnetic backgrounds is poorly understood. Here, we show that spiral multiferroics, some of the most basic non-collinear magnets, host bimerons, a particular type of skyrmion. Multiferroic properties of a spin spiral endow the bimeron with magnetic and ferroelectric dipole moments that, surprisingly, depend on its position relative to the spiral. This enables precise positioning of the bimeron by a rotating magnetic field (e.g. of a circularly polarized electromagnetic wave). At low frequencies, the bimeron magnetic moment rotates in sync with the field, and this topological spin texture is pumped in the Archimedean screw fashion. The results establish spiral multiferroics as a natural racetrack, where one full rotation of the field moves the bimeron by one spiral period.

MA 43.3 Fri 10:00 H16

Pathways to Bubble and Skyrmion Lattice Formation in Fe/Gd Multilayers — Tim Titze[1], Sabri Koraltan[2], Timo Schmidt[3], Dieter Suess[2], Manfred Albrecht[3], Stefan Mathias[1], and •Daniel Steil[1] — [1]University of Goettingen — [2]University of Vienna — [3]University of Augsburg

Fe/Gd multilayers host a rich variety of magnetic textures, including topologically trivial bubbles and topologically protected skyrmions [1-4]. Using time-resolved Kerr spectroscopy, we highlight how different control strategies including temperature T, out-of-plane magnetic fields H and femtosecond light excitation can be used to create such textures via different pathways. We find that varying the magnetic field at constant temperature leads to a different (H,T) phase diagram of magnetic textures than moving along a temperature trajectory at constant magnetic field, which is corroborated by micromagnetic simulations. We furthermore show that bubble and skyrmion (BSK) creation by impulsive light excitation is at least partially a non-adiabatic process, as the creation occurs in parts of the (H,T) phase diagram, where neither the constant T nor the constant H trajectory predict their existence. We discuss a possible scenario for the creation of BSKs in this material system involving the inhomogeneity of the excitation process.

[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.*, Adv. Funct. Mater. **34**, 2313619 (2024)
[4] T. Titze *et al.*, Phys. Rev. Lett. **133**, 156701 (2024)

MA 43.4 Fri 10:15 H16

Nitrogen-vacancy scanning imaging of a room-temperature skyrmion lattice in a van der Waals ferromagnet Fe3-xGaTe2 — •Young-Gwan Choi[1], Hayden Binger[1], Luke Turnbull[1], Yejin Lee[1], Lotte Boer[1], Chenhui Zhang[2], Haneul Kim[3], Claire Donnelly[1], Hyunsoo Yang[2], and Uri Vool[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Department of Electrical and Computer Engineering, National University of Singapore, 117583 Singapore, Singapore — [3]Department of Physics, University of Ulsan, 44610 Ulsan, Korea

We report the visualization of the magnetic stray field from a room-temperature skyrmion lattice in the van der Waals ferromagnet Fe3-xGaTe2(FGaT) by nitrogen-vacancy (NV) scanning. By employing a field-cooled process, we observed the transition from labyrinth domain structures to a stable skyrmion lattice state, demonstrating the formation of a stable skyrmion lattice phase. The experiments were conducted on FGaT flakes with an approximate thickness of 100 nm, revealing detailed insights into the stable formation of the skyrmion phase even at room temperature. These results highlight the capability of NV scanning for direct and quantitative imaging of room-temperature skyrmions, offering valuable insights into their properties and advancing the understanding of skyrmion lattices. This study provides a basis for further exploration of skyrmion-based spintronic applications.

MA 43.5 Fri 10:30 H16

Controlling topolopogical spin textures in Heusler magnetic nanowires — •Rikako Yamamoto[1,2], Luke Turnbull[1,2], Marisel Di Petro Martinez[1,2], Jeffrey Neethirajan[1], José Claudio Corsaletti Filho[1], Simone Finizio[3], Tim Butcher[3,4], Igor Beinik[5], Claas Abert[6], Dieter Suess[6], Praveen Vir[1], Chandra Shekar[1], Claudia Felser[1], and Claire Donnelly[1,2] — [1]MPI-CPfS, Dresden, Germany — [2]WPI-SKCM2, Higashi-Hiroshima, Japan — [3]PSI, Villigen, Switzerland — [4]MBI, Berlin, Germany — [5]MAX-IV, Lund, Sweden — [6]University of Vienna, Vienna, Austria

Nontrivial topological spin textures, such as magnetic skyrmions and antiskyrmions, have been attracting considerable interest due to their fundamental properties and potential applications. Antiskyrmions, commonly found in materials with anisotropic Dzyaloshinskii-Moriya interactions, are of particular interest due to their complex winding, and prospect for unidirectional motion. However, such textures are energetically degenerate, and their formation remains open to exploration. Here we gain control over the formation and stability of anti-skyrmions by nanopatterning anti-skyrmion-hosting Heusler magnets. By patterning nanowires oriented at different angles to the crystallographic unit cell, we combine intrinsic and geometrical anisotropies. Using x-ray dichroic ptychography to image the magnetic configuration of these nanowires, we observe that the competition between geometrical and intrinsic anisotropy can lead to preferential formation of topological objects in the nanostructure. This approach provides new opportunities for enhanced control of topological spin textures.

MA 43.6 Fri 10:45 H16

Confinement-Induced Magnetoresistances in Skyrmion-based Magnetic Tunnel Junctions — •Moritz Winterott[1,2] and Samir Lounis[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

Innovations are essential to address the rapidly growing demand for data. One of the most promising solution are magnetic tunnel junctions [1] (MTJs) which utilize spin-dependent tunnelling between two ferromagnetic layers separated by an insulating barrier and present a high-speed, non-volatile, and energy-efficient memory solution. Combining MTJs with skyrmions offers great potential [2] due to the nanoscale size and topological protection of the later ones. However creation and efficient electrical detection of skyrmions in MTJs remains challenging. We demonstrate that a strong splitting of spin-channels leads to confined states inside the skyrmion, complementary to Friedel oscillations reaching far outside the skyrmion. These non-trivial signatures in the electronic structure induce new magnetoresistances augmenting the efficiency of those enabled by spin-orbit coupling and magnetic non-collinearity [3], which could facilitate electrical detection of skyrmions in MTJs. We employ a tight-binding scheme to explore the impact of the skyrmion size, Fermi energy and splitting of the spin-channels.

– [1] Parkin et al., Nat. Mater. 3, 862 (2004); [2] Chen et al., Nature 627, 522-527 (2024); [4] Fernandes et al., Nat. Com. 13, 1576 (2022).

MA 43.7 Fri 11:00 H16

Field-induced Reversal of Magnetic Anisotropy in Skyrmion Hosts — •Hans-Albrecht Krug von Nidda, Bertalan Szigeti, Mamoun Hemmida, Dieter Ehlers, and István Kézsmárki — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86135 Augsburg, Germany

Skyrmions show up in non-centrosymmetric magnets due to the complex interplay of anisotropic Dzyaloshinskii-Moriya interaction, uniaxial magnetic anisotropy, and magnetic dipolar interactions. A magnet is commonly classified as either easy-axis or easy-plane, when the magnetic anisotropy forces the magnetization to align parallel or perpendicular to the high-symmetry axis, respectively. We show that this simple classification fails for systems with competing anisotropy terms. Our multi-frequency electron spin resonance spectroscopy study on the skyrmion hosts GaMo4S8 and GaV4Se8 reveals counteracting exchange and g-factor anisotropies. Consequently, the total aniotropy changes sign in moderate magnetic fields: GaMo4S8 turns from an easy- to a hard-axis magnet, while GaV4Se8 does the opposite. These findings underscore the significance of precisely quantifying all anisotropy components, because a single effective value, when encompassing conflicting terms, proves to be insufficient for an accurate description of magnetic states.

MA 43.8 Fri 11:15 H16

Short-pitch skyrmions in layered rare-earth frustrated magnets — •Vladislav Borisov[1], Rohit Pathak[1], Sagar Sarkar[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

While most skyrmionic systems rely on the presence of Dzyaloshinskii-Moriya interaction (DMI), there are a few known compounds, such as $GdRu_2Si_2$ with 122-type structure, where extremely compact skyrmions around 2 nm are stabilized without DMI, as discovered in recent experiments [1]. Several theory studies, including our recent work [2], suggest the importance of magnetic frustration and local anisotropy for the skyrmion stability. The present work explores further the variety of magnetic phases in other compounds with the 122-type crystal structure using density functional theory and atomistic spin dynamics at finite temperature and applied magnetic field. Various chemical compositions, included those from [3], are considered here and interesting trends for RKKY-like Heisenberg interactions between the rare-earth moments, calculated using magnetic force theorem, and real-space textures are analyzed.

1. N. D. Khanh et al., Nature Nanotech. 15, 444-449 (2020).
2. S. Sarkar et al., arXiv:2409.06736.
3. T. Nomoto, R. Arita, J. Appl. Phys. 133, 150901 (2023).

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15 min. break

MA 43.9 Fri 11:45 H16

Tunable magnetic skyrmion bubbles in centrosymmetric magnets — Dola Chakrabartty[1], István Kézsmárki[1], and •Ajaya Kumar Nayak[2] — [1]Experimentalphysik V, Center for Electronic Correlations and Magnetism, Institute for Physics, Augsburg University, D-86135 Augsburg, Germany — [2]School of Physical Sciences, National Institute of Science Education and Research, HBNI, Jatni, 752050, Bhubaneswar, India

Magnetic skyrmions are topologically protected spin textures that can avoid defects and be mobilized by low current densities, making them potential candidates for high-density and low-power consuming logic and memory devices. Skyrmion-like spin textures with different helicities and vorticities have recently been found also in centrosymmetric magnets, stabilized by competing dipolar interaction and out-of-plane magnetic anisotropy. The primary motivation of this study is to explore the extensive tunability of magnetic skyrmion bubbles in centrosymmetric magnets with internal and external parameters. We have demonstrated that in the centrosymmetric system by applying external magnetic field and tuning magnetic anisotropy one can transform skyrmions (topological number -1) to type-II bubble (topological number 0) through Bloch line formation. We found that the skyrmions are stable when there is only out-of-plane uniaxial anisotropy, whereas the introduction of small in-plane anisotropy turns them to type-II bubbles. Presently, we are in the process of exploring the tunability of skyrmions in such systems with other external stimuli, such as uniaxial strain and laser irradiation.

MA 43.10 Fri 12:00 H16

Gate-Voltage-Induced Changes of the Magnetic Properties of Skyrmion-Hosting Gd/Fe Multilayers — •Sebastian Hofmann[1], Steffen Wittrock[2], Tamer Karaman[1], Sascha Petz[2], Daniel Metternich[2], Krishnanjana Puzhekadavil Joy[2], Kai Litzius[1], and Felix Büttner[1,2] — [1]Universität Augsburg Institut für Physik, Universitätsstraße 1, 86159 Augsburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin

Ionic gating has recently emerged as a versatile method to induce large and controllable changes of the local magnetic properties of thin films. This allows, for example, to manipulate the existence [1] and chirality [2] of magnetic skyrmions. However, existing gating experiments have focused on ultrathin films, where skyrmions are usually micron sized. Here, we show that ionic gating with oxygen and hydrogen can be used to control ferrimagnetic Gd/Fe multilayer materials with thicknesses of more than 40 nm, in which sub-100 nm skyrmion can be observed. We find that ionic gating can shift the compensation temperature by more than 100 K, i.e., by a similar magnitude as in sub-10 nm thick films [3]. However, unlike ultrathin films, our thicker materials exhibit vertical variation of magnetic properties, suggesting a pathway toward gate-control of spin textures in 3D. [1] Yang, S. et al. Adv. Mat. 2208881 (2022). [2] Fillion, C.-E. et al. Nat. Comm. 13, 5257 (2022). [3] Huang, M. et al. Nat. Nanotechnol. 16, 981 (2021).

MA 43.11 Fri 12:15 H16

Shape anisotropy in helimagnets — •Jan Masell[1], Maurice Colling[2], Mariia Stepanova[2], Mario Hentschel[3], and Dennis Meier[2] — [1]Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]NTNU Norwegian University of Science and Technology, Trondheim, Norway — [3]University of Stuttgart, Stuttgart, Germany

In chiral magnets, the competition between ferromagnetic exchange and Dzyaloshinskii-Moriya interaction (DMI) stabilizes a long-ranged helical state as the ground state. The orientation and pitch of the helix is described by the q-vector. For isotropic model systems, the q-vector can point in any direction while in real materials its orientation is pinned by anisotropies, such as exchange or single ion anisotropy.

In this talk, I will discuss the impact of the shape of the magnet on the orientation of the helical phase. While shape anisotropy is a well-established phenomenon in ferromagnets, its role in chiral magnets remains less explored. I will present our theoretical results for a new type of DMI-shape-anisotropy for non-trivial magnetic textures, caused by the competition between standard shape anisotropy and the chiral surface twist inherent to systems with DMI. Our experimental data on FeGe confirm the existence of such non-trivial anisotropy, challenging present models for magnetic textures in nanostructures with DMI.

MA 43.12 Fri 12:30 H16

Extraordinary return point memory of Pt/Co/Dy ferrimagnetic multilayers — •Tamer Karaman[1], Kai Litzius[1], Sebastain Wintz[2], Aladin Ullrich[1], Daniel Metternich[1,2], Steffen Wittrock[2], Krishnanjana Joy[1,2], Sebastian Hoffman[1], Timo Schmidt[1], Manfred Albrecht[1], and Felix Büttner[1,2] — [1]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany — [2]Helmholtz-Zentrum Berlin, 14109 Berlin, Germany

Chiral magnetic spin textures are promising candidates for various spintronics applications [1]. These applications rely fundamentally on the controlled motion of spin textures under external stimuli. In this study, we report on the contrary and unique behaviour of Pt/Co/Dy rare-earth transition metal (RE-TM) ferrimagnetic multilayers, particularly their demonstration of full return-point memory. By studying the domain and domain wall response with field cycling using real-space imaging techniques, we observe deterministic behaviour where domains completely return to their original positions, even after exposure to high applied fields. Such observation is rarely documented in the literature and invites a variety of interpretations [2, 3]. This study emphasizes the significance of unexplored aspects of RE-TM ferrimagnets, advancing deeper exploration and broader utilization of these materials.

1. Fert, A. et al. Nat. Rev. Mater. 2, 17031 (2017). 2. Kappenberger, P. et al. Phys. Rev. Lett. 91, 267202 (2003). 3. Seu, K. A. et al. New J. Phys. 12, 035009 (2010).

MA 43.13 Fri 12:45 H16

Fascinating mesoscale magnetic textures in the topological Kagome system $TbMn_6Sn_6$ — •Ralph Rajamathi[1], Manuel Zahn[1,2], Kai Litzius[1], István Kézsmárki[1], and Sándor Bordács[3] — [1]Center for Electronic Correlations and Magnetism, University of Augsburg — [2]Department of Materials Science and Engineering, Norwegian University of Science and Technology — [3]Department of Physics, Budapest University of Technology and Economics

In recent years, the Kagome ferrimagnet $TbMn_6Sn_6$ has garnered significant interest due to its unconventional band topology, which realizes exotic quantum states like a Chern insulating phase. It exhibits a spin-reorientation transition (SRT) from easy-axis to easy-plane at 310 K, where skyrmion bubbles have been observed in lamellae. However, magnetic textures in bulk crystals have been unexplored so far. Here, we used magnetic force microscopy (MFM) to image the magnetic pattern on the surface of bulk crystals, and magnetometry to study the role of second order magnetic anisotropy. Two types of textures were observed, namely long-ranged stripes that invert contrast on reversing the tip's magnetization, decorated by star-shaped structures whose contrast is independent from the the tip's magnetization. Reorientation of the stripes and creation/elimination of the "stars" in an external magnetic field indicate low magnetic pinning. Analyzing the in-plane magnetometry data, a metastable magnetization state was observed below the SRT temperature, indicating the possibility of an intermediate in-plane state, which was observed by MFM in the vicinity of SRT.

MA 43.14 Fri 13:00 H16

Domain walls with 90° magnetization rotation in the topological kagome magnet $TbMn_6Sn_6$ — •Manuel Zahn[1,2], Ralph Rajamathi[1], Kai Litzius[1], Dennis Meier[2], Sándor Bordács[3], and István Kézsmárki[1] — [1]Center for Electronic Correlations and Magnetism, University of Augsburg — [2]Department of Materials Science and Engineering, Norwegian University of Science and Technology (NTNU) — [3]Department of Physics, Budapest University of Technology and Economics

The layered Kagome ferrimagnet, $TbMn_6Sn_6$, attracts much attention due to its topologically non-trivial features. The bulk electronic band structure realizes a Chern insulating state and in the real space, skyrmion bubbles have been observed in thin lamellae of this compound. $TbMn_6Sn_6$ exhibits a zero-field first-order spin reorientation transition at $T_{SR} = 315$ K, below/above which the magnetic moment points perpendicular/parallel to the Kagome plane. Here, using magnetic force microscopy, we reveal peculiar domain textures in the vicinity of T_{SR} on the surface of bulk $TbMn_6Sn_6$ crystals. Upon approaching T_{SR} from lower temperatures, we observed a broadening of the domain walls separating regions oppositely magnetized perpendicular to the Kagome plane, and the emergence of a strictly in-plane magnetized region at the center of the walls. We compared these results with analytical calculations based on a continuum magnetic model and found that the $\pi/2$ stepwise rotation of the magnetization is a universal effect at the spin reorientation transition.

MA 44: Focus Session: Physics of the van der Waals Magnetic Semiconductor CrSBr II (joint session HL/MA)

The joint focus session of the divisions HL and MA presents the latest developments of the rapidly growing community working with the van der Waals magnetic semiconductor CrSBr with distinct excitonic and magnetic properties, and it is organized by Shengqiang Zhou (HZ Dresden-Rossendorf), Farsane Tabata-Vakili (TU Braunschweig), and Florian Dirnberger (TU Munich).

Time: Friday 9:30–13:00 Location: H17

Invited Talk MA 44.1 Fri 9:30 H17

Constructing Artificial Matter in the Electron Microscope - Atomic Fabrication at Scale in CrSBr — •Julian Klein — Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, 02319 MA, USA

The ability to control the arrangement of individual atoms has transcended naturally occurring configurations of matter, enabling experimental breakthroughs in quantum physics. I will show how we can now use scanning transmission electron microscopy to construct artificial atomic arrangements at scale and demonstrate it with the layered magnetic quasi-1D semiconductor CrSBr. By developing strategies to position the electron beam with picometer precision and perform rapid, targeted beam actions, we achieve deterministic control over the movement of Cr atoms in space and time. With this capability, we selectively steer Cr atoms into interstitial positions, forming localized quantum states while simultaneously monitoring atomic movements in real time with microsecond resolution. Fully automating the electron microscope enables us to construct ordered arrays of Cr interstitial superlattices atom by atom as well as nonperiodic structures, spanning hundreds of locations over tens of nanometers, all within minutes. Our results show that atomic fabrication at scale in the electron microscope is now a reality, unlocking unprecedented opportunities to construct quantum defects and phases, atom by atom, in the solid state, that extend over macroscopic length scales.

Invited Talk MA 44.2 Fri 10:00 H17

Tuning the structure and magnetism in CrSBr via external pressure — •Ece Uykur — Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

As one of the two-dimensional (2D) van der Waals (vdW) magnets, CrSBr regained significant attention recently because it is air-stable even in the monolayer form making this compound very attractive. It shows strong coupling between its magnetic, electronic, structural, and optical properties [1]. Several ab initio calculations put forward the importance of the balance between Cr-Cr direct exchange and Cr-anion-Cr superexchange interactions and showed that the A-type antiferromagnetism in this compound is delicately balanced with these short- and long-range magnetic interactions [2]. Therefore, studies exploring the tunability of the inter- and inralayer coupling are important and one plausible experimental strategy is the external pressure.

In this talk, I will summarize our recent efforts on high-pressure single crystal XRD and magnetization studies on CrSBr. We performed single crystal XRD studies up to ∼20 GPa, which reveals a non-monotonous behavior of Cr-ion in the structure along with a structural phase transition above 17 GPa. The movement of this Cr-ion has also direct link with the magnetization of the compound that is studied with the high-pressure magnetic susceptibility measurements up to ∼8 GPa.

[1] K. Lin et al., ACS Nano 18, 2898 (2024) [2] J. Cenker et al., Nat. Nanotechnol. 17, 256 (2022).

Invited Talk MA 44.3 Fri 10:30 H17

A theoretical perspective on exciton-magnon coupling and its implications — •Akashdeep Kamra — Department of Physics, Rheinland-Pfälzische Technische Universität (RPTU) Kaiserslautern-Landau, Kaiserslautern, Germany

The dependence of exciton energies on the magnetic order in CrSBr has opened avenues for controlling optical properties using magnetic fields. Conversely, it has enabled an optical time-resolved sensing of the magnetic degrees of freedom. This has further been exploited to investigate the interplay between excitons and magnons, the excitations of the magnetic order. We will discuss how excitonic energies offer a convenient access to coherent as well as thermal magnon dynamics. Focusing on transport, we will discuss the recent observation of the magnon-exciton drag effect that makes it feasible to leverage thermal magnon currents for transporting excitons at unexpectedly fast velocities. Finally, we will conclude with a brief discussion of emergent non-linearities in exciton energies mediated by the magnonic modes in the canted magnetic state of CrSBr.

References:

1. F. Dirnberger et al., Magneto-optics in a van der Waals magnet tuned by self-hybridized polaritons, Nature 620, 533 (2023).
2. F. Dirnberger, S. Terres, Z. A. Iakovlev, K. Mosina, Z. Sofer, A. Kamra, M. M. Glazov, and A. Chernikov, Exciton transport driven by spin excitations in an antiferromagnet (unpublished).
3. B. Datta et al., Magnon-mediated exciton-exciton interaction in a van der Waals antiferromagnet, arXiv:2409.18501.

15 min. break

Invited Talk MA 44.4 Fri 11:15 H17

Exciton and valley properties of monolayer transition metal dichalcogenides on the van der Waals magnetic semiconductor CrSBr — •Yara Galvao Gobato — Universidade Federal de Sao Carlos, Sao Carlos, Brazil

Chromium sulfide bromide is a promising van der Waals (vdW) magnetic material, undergoing a magnetic phase transition to an A type antiferromagnetic state below the Neél temperature of about 132K in its bulk form. VdW heterostructures composed of monolayer transition metal dichalcogenides (TMDs) and vdW magnetic materials such as CrSBr are an interesting platform to modify valley and excitonic properties of non-magnetic TMDs. In this talk, we will present our recent results on optical and magneto-optical properties of monolayer TMDs on CrSBr under different magnetic field orientations. Remarkably, we have observed a clear influence of the CrSBr magnetic order on the exciton and valley properties of monolayer TMDs, such as an anomalous linear polarization dependence, unsual temperature dependence of emission energies, magnetic field dependence of the emission intensity, and valley g-factor values with clear signatures of an asymmetric magnetic proximity exchange interaction. Our results are explained by asymmetric magnetic proximity effects, charge transfer and a possible contribution of exciton/trion magnon coupling. Our studies suggest that vdW heterostructures with antiferromagnetic nonmagnetic interfaces are interesting platforms to modify the valley and excitonic properties of TMDs for possible applications in opto-spintronics and quantum technology.

MA 44.5 Fri 11:45 H17

Ab initio studies on the electronic and optical properties of magnetic CrSBr — •Marie-Christin Heissenbüttel[1], Pierre-Maurice Piel[2], Julian Klein[3], Thorsten Deilmann[1], Ursula Wurstbauer[2], and Michael Rohlfing[1] — [1]Institute of Solid State Theory, University of Münster, Germany — [2]Physical Institute, University of Münster, Germany — [3]Department of Materials Science and Engineering, MIT, Massachusetts, USA

CrSBr recently emerged as a van der Waals layered material exhibiting intriguing electronic and optical properties arising from the intricate interplay between crystal structure and layered magnetic order. A thorough understanding of these effects is essential to assess its potential for applications in spintronic and quantum devices. Due to the large crystal anisotropy, the monolayer, multilayer, and bulk crystal CrSBr show a quasi-one-dimensional behaviour of effective masses and exciton wavefunctions [1]. The interlayer antiferromagnetic (AFM) coupling suppresses layer to layer interactions in the magnetic ordered low temperature phase, resulting in strong quantum confinement of electrons and excitons within the individual layers [2]. Using ab-initio GW/Bethe-Salpeter equation calculations, we analyze electronic and excitonic properties on the same footing and elucidate how the AFM van der Waals stacking, symmetry properties and the large crystal

anisotropy govern the electronic and optical properties of this material.
[1] https://doi.org/10.1021/acsnano.2c07316
[2] https://doi.org/10.48550/arXiv.2403.20174

MA 44.6 Fri 12:00 H17

Internal structure and ultrafast dynamics of quasi- 1D excitons controlled by magnetic order — •N. Nilforoushan[1], M. Liebich[1], M. Florian[2], F. Mooshammer[1,3], A. D. Koulouklidis[1,3], L. Wittmann[1], K. Mosina[4], Z. Sofer[4], F. Dirnberger[5], M. Kira[2], and R. Huber[1,3] — [1]Dept. of Physics, University of Regensburg, Germany — [2]Dept. of Electrical Engineering and Computer Science, University of Michigan, USA — [3]RUN, University of Regensburg, Germany — [4]Dept. of Inorganic Chemistry, University of Chemistry and Technology Prague, Czech Republic — [5]Dept. of Physics, Technical University of Munich, Germany

In van der Waals (vdW) layered crystals, Coulomb correlations are often tuned by structural engineering, giving rise to emergent phenomena such as tightly bound excitons and exotic electronic and magnetic phases. Magnetic vdW materials offer a unique platform for in situ control of Coulomb correlations enabled by their intrinsic magnetic order. Here, we present quantitative experiment-theory proof that excitonic correlations can be tailored through spin order in the vdW magnet CrSBr. By probing internal transitions of excitons with phase-locked mid-infrared pulses, we reveal their binding energy and strong anisotropy of their quasi-1D orbitals resulting in significant fine-structure splitting. We switch excitons from monolayer-localized to interlayer-delocalized species by pushing the system from the antiferromagnetic to the paramagnetic phase. The exciton's ultrafast dynamics further support this scenario. In future applications, excitons may be interfaced with spintronics enabling on-demand phase transitions.

MA 44.7 Fri 12:15 H17

Raman controlled lithium intercalation into CrSBr van der Waals structure — •Kseniia Mosina, Aljoscha Söll, Martin Veselý, Jiří Šturala, and Zdenek Sofer — Department of Inorganic Chemistry, University of Chemistry and Technology Prague, 166 28 Prague 6, Czech Republic.

Lithium intercalation into the van der Waals crystalline structure of layered transition metal dichalcogenides by means of chemical and electrochemical intercalation is a well-known method for studying semiconductor-metallic phase transitions. The layered semiconductor chromium sulphur bromine (CrSBr) in recent years becomes an ultimate playground for the studies of low-dimensional magneto-optical properties. The interlayer distance of CrSBr allows the easy cleavage and intercalation of the guest molecules within the crystalline structure. Conveniently air-stable, this material exhibits a direct band gap of 1.5 eV, an antiferromagnetic state in bulk and ferromagnetism in the monolayer. Here, we present the lithium intercalation method into the CrSBr structure by lithium-solvated electron solution. To monitor the lithiation process in real-time, we investigated the Raman spectra evolution upon lithium ion intercalation into a few-layered CrSBr flake. Our findings suggest that the quasi-one dimensional nature of CrSBr leads to weak interlayer hybridization along the b-direction, which facilitates the diffusion of guest ions by lowering the migration energy barrier and enables anisotropic Li+ diffusion. The reliable intercalation methodology allows tracking the intercalation process directly in the desired area favorable for device fabrication.

Invited Talk MA 44.8 Fri 12:30 H17

Electric field control of intra- and interlayer excitons in CrSBr — •Nathan Wilson[1], Amine Ben Mhenni[1], Ferdinand Menzel[1], Alain Dijkstra[1], Zdenek Sofer[2], and Jonathan Finley[1] — [1]Walter Schottky Institute, TU Munich, Garching, Germany — [2]Institute of Chemistry and Technology, Prague, Czech Republic

In the 2D magnetic semiconductor CrSBr, the interplay between a direct bandgap for all layer thicknesses and layered antiferromagnetism with strong magneto-electronic coupling give rise to rich but poorly understood excitonic physics. So far, the presence of two closely spaced conduction bands and existence of both intra and interlayer excitons in multilayers has complicated interpretation of the optical spectrum of its excitons. Here, we study monolayers and bilayers of CrSBr in dual-gated structures, allowing for independent tuning of electric field and charge doping. Our study reveals the existence of the previously unobserved ground state exciton in monolayers, which is darkened both by charge doping and electric field. We find that both intralayer and hybrid intra/interlayer excitons are highly sensitive to the vertical electric field, implying a reasonably large exciton polarizability and control over wavefunction symmetry. With this information, we are able to form a more complete picture of the real space and band character of the excitons in CrSBr.

MA 45: Computational Magnetism

Time: Friday 9:30–12:30 Location: H18

MA 45.1 Fri 9:30 H18

Magnetic Interactions and Spin Coupling in Endohedral Fullerene Nanostructures — •Arkamita Bandyopadhyay and Jamal Berakdar — Martin-Luther-Universität Halle-Wittenberg, Karl-Freiherr-von-Fritsch-Str. 3 06120 Halle/Saale

Our work investigates the spin-spin interactions in endohedral fullerene clusters, with a particular focus on the effects of different cluster geometries (linear, triangular, and more complex arrangements). By examining various configurations, we aim to provide a deeper understanding of how the interactions between spins in these clusters are governed by both the unique structural features of the fullerene molecules and their molecular levels. Our compuational study explores the role of spin exchange interactions, the potential for spin frustration, and how these phenomena can be manipulated to achieve desired magnetic behaviors, thus it can guide the design of new materials for spintronic devices, quantum information processing, and other applications where precise control over spin-spin interactions is key.

MA 45.2 Fri 9:45 H18

Intrinsic Spin Nernst Effect and Chiral Edge Modes in vdW Ferromagnetic Insulators: Dzyaloshinskii-Moriya vs. Kitaev Interactions — •Verena Brehm and Alireza Qaiumzadeh — NTNU Trondheim, Norway

The thermomagnetic Nernst effect and chiral edge states are key signatures of nontrivial topology and emerging Berry curvature in magnonic systems. Implementing atomistic spin simulations, we theoretically demonstrate the emergence of chiral magnon edge states at the boundaries of a ferromagnetic hexagonal lattice in the presence of Dzyaloshinskii-Moriya and Kitaev interactions, which are robust against nonlinear magnon interactions. In our simulations, we consider the spin parameters of CrI3 as a prototype of van der Waals magnetic layers. We show that the spin accumulation is reduced in the presence of Kitaev spin interactions compared to systems governed by Dzyaloshinskii-Moriya interactions. This reduction stems from the breaking of the U(1) symmetry, which leads to a shorter spin coherence length imposed by the Kitaev interaction. We propose that measuring the angular dependence of the Nernst signal in a magnetic field provides an effective indirect method for identifying the microscopic origin of topological magnons. Our findings hold promising potential for advancing next-generation energy-harvesting Nernst materials and facilitating the integration of topological magnetic materials with spintronic-based quantum technologies.

MA 45.3 Fri 10:00 H18

Origin of MAE and second order MAE due to the magnetostriction in tetragonal systems - FePt study — •Dominik Legut[1] and Pablo Nieves[2] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czechia — [2]University of Oviedo, Oviedo, Spain

The origin of magnetocrystalline anisotropic energy (MAE) guided by spin-orbit coupling in the $L1_0$-FePt alloy was analyzed and the correlations among MAE and magnetoelastic (magnetostriction) constants $b's(\lambda's)$ by means of the electronic structure eigenvalues (orbital energies) and eigenfunctions (orbital occupancies) were established[1]. Our numerical analysis includes the convolution of the projected wavefunction (density of states) of each orbital of the Fe and Pt sub-lattices into their orbital energies and its contribution to the MAE,$b's$, and $\lambda's$. However, this corresponds to the zero strain situation. For a zero stress (realistic conditions used in experiments) situtation a very small correction is found for the first anisotropy constant $\Delta K_1/K_1 = 0.07\%$, while a much more significant contribution is obtained for the second one $\Delta K_2/K_2 = 21.86\%$. General analysis of this effect for tetragonal crystals is provided, finding that ΔK_1 will be always positive for any stable phase with this symmetry[2].

References:
1. T. Das, P. Nieves, D. Legut, J. Phys. D: Appl. Phys. **58**, 035004 (2025)
2. D. Legut, P. Nieves, Solid State Sciences (accepted)

MA 45.4 Fri 10:15 H18

High-throughput workflow for predicting magnetic ground states — •Hao Wang and Hongbin Zhang — Technical University of Darmstadt, 64287 Darmstadt, Germany

Obtaining the correct magnetic ground state is crucial for understanding the nature of magnetism and serves as a foundation for engineering functional magnetic materials for interesting applications. In this work, we present a high-throughput computational workflow designed to accurately determine the exchange interaction J_{ij} matrices and other relevant parameters for a wide range of magnetic systems. Combining the four-state energy mapping method with the Green's function approach, we construct symmetrized Heisenberg Hamiltonians to model magnetic interactions. Furthermore, by integrating atomistic spin dynamics Vampire package, our framework enables the efficient prediction of magnetic ground states. This scalable workflow not only improves computational efficiency for complex magnetic materials but also provides a robust platform for exploring the fundamental properties of magnetic systems.

MA 45.5 Fri 10:30 H18

Semiclassical approach to the exchange interactions and spin waves in double-layered antiferromagnets — Seo-Jin Kim[1], Zdeněk Jirák[2], Jiří Hejtmánek[2], Karel Knížek[2], Helge Rosner[1], and •Kyo-Hoon Ahn[2] — [1]Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden, Germany — [2]Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czechia

We investigate the stability and magnonic properties of double-layered antiferromagnets using two model systems—the linear chain (LC) and a more complex railroad trestle (RT) geometry—as well as the real solid antiferromagnetic (AFM) CrN in its rock-salt structure. In the LC model, the spin-paired order $(\cdots{+}{+}{-}{-}\cdots)$ requires alternating ferromagnetic (FM) and AFM interactions. In contrast, the RT geometry allows some frustration, and the spin-paired order can be stable even for all magnetic exchange interactions being AFM. In the hypothetical cubic phase of CrN, magnetic Cr ions form a face-centered cubic lattice with equivalent AFM links to twelve nearest neighbors. However, the magnetostructural transition to an orthorhombically distorted phase below the Néel temperature ($T_N = 287$ K) diversifies the Cr-Cr nearest-neighbor distances, suppressing frustration. Using *ab initio* exchange parameters, we calculate the magnon dispersion relation and the temperature-dependent evolution of ordered magnetic moments. Our findings demonstrate that the stability of the double-layered AFM structure in CrN is attained, even when intra-sublattice interactions remain all AFM, consistent with the RT model.

MA 45.6 Fri 10:45 H18

Tuning Magnetic Anisotropy in Fe3Y Through Transition Metal Doping: An Ab-Initio High-Throughput Study — •Md Nur Hasan and Heike Herper — Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120, Uppsala, Sweden

The advancement of permanent magnet systems is essential for various applications, including energy generation and information technology. This research focuses on developing and optimizing new permanent magnetic materials using an ab initio based first-principles approach. The Fe3Y system was initially selected for its in-plane magnetic anisotropy with a Curie temperature of 550 K, which, although advantageous, constrains its use in scenarios that require uniaxial (out-of-plane) anisotropy. The main goal of this study is to transition the magnetic anisotropy from the in-plane to a uniaxial configuration. Various transition metals were systematically introduced into both the Y and Fe sites of the Fe3Y structure to facilitate this shift. This doping approach enabled the tuning of the magnetic properties and provided insight into the mechanisms governing magnetic anisotropy. As a result, we identified several promising compositions with significant alterations in magnetic behavior, including systems that exhibit uniaxial anisotropy with Curie temperatures of ~ 550K, making them suitable for high-performance magnetic applications. Initial findings suggest that certain transition metal dopants can significantly modify spin-orbit coupling and crystal field effects, achieving the desired anisotropy realignment with the potential to discover a new category of high-performance permanent magnets.

15 min. break

MA 45.7 Fri 11:15 H18

Programmable Magnetophononics: Selective Damping of Surface Acoustic Waves — •Michael Karl Steinbauer[1], Peter Flauger[1], Bernhard Emhofer[1], Matthias Küss[2], Stephan Glamsch[2], Manfred Albrecht[2], and Claas Abert[1] — [1]University of Vienna — [2]University of Augsburg

Surface acoustic wave (SAW) bandpass filters are an indispensable part of modern telecommunications infrastructure [1]. Spin waves (SWs) can be excited by SAWs in radio-frequency bands, making their coupling a topic of current scientific interest [2].

In this work, we utilize this magnon-phonon interaction to demonstrate the theoretical viability of a novel device composed of exchange-decoupled magnetic islets on a piezoelectric substrate. Depending on the magnetic orientation of neighboring islets, a shift in the dispersion relation of the SW is predicted to occur due to their stray field interaction. This shift increases or decreases the efficiency with which the SAW can excite the SWs, leading to a difference in the amount of energy the magnetic system absorbs. For certain geometries, a gap in the SAW power after traversing the device of 10 dB/mm or more is predicted to occur.

For this study, a new algorithm for efficiently calculating SAW attenuation under the assumption of a continuous signal was developed for the micromagnetic simulation library magnum.np [3].

[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 45.8 Fri 11:30 H18

Mean-Field Approximation and ab-initio calculations in Tetragonal Mn_2-based Heusler compounds. — •Jorge Cardenas-Gamboa[1,5], Arthur Ernst[2], Maia G Vergniory[3,4], Edouard Lesne[1], Claudia Felser[1], and Paul McClarty[6] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Johannes Kepler University of Linz, Linz, Austria. — [3]Donostia International Physics Center, Donostia-San Sebastian,Spain — [4]Université de Sherbrooke, Sherbrooke J1K 2R1 QC, Canada. — [5]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [6]Universite Paris-Saclay, Gif-sur-Yvette, France.

Achieving flexible control over magnetic properties is possible in multicomponent systems consisting of several magnetic sublattices with competing interactions.In 2014, Meshcheriakova et al. demonstrated that the Heusler compound Mn_2RhSn exhibits substantial strong noncollinearity and its magnetic structure undergoes a spin-reorientation transition, driven by the competition between its magnetic sublattices. In this work, we use a mean-field approximation to analyze the exchange interactions between the sublattices and investigate how different magnetic regimes develop as a function of temperature. Additionally, we perform first-principles calculations to derive the exchange interactions and assess their influence on the magnetic properties, extending our analysis to other tetragonal Heusler magnets. We then explore the topological properties that arise from the magnetism, focusing on the Weyl nodes and surface states.

MA 45.9 Fri 11:45 H18

First-Principles Study of Non-Collinear Magnets: Spin Models and Cluster Multipole Theory — •Juba Bouaziz[1,2], Takuya Nomoto[3], and Ryotaro Arita[1,2,4] — [1]RCAST, University of Tokyo, Japan — [2]CEMS, RIKEN (Wako), Japan — [3]Tokyo Metropolitan University, Japan — [4]Department of Physics, University of Tokyo, Japan

We present a computational approach for modeling complex noncollinear magnets using the cluster multipole (CMP) method [1] to determine symmetry-allowed magnetic configurations. The magnetic ground state is obtained by comparing the energies of candidate CMP solutions within a spin model Hamiltonian that includes isotropic exchange interactions, relativistic anisotropic terms, and higher-order biquadratic interactions. The parameters of the spin model are systematically calculated using the magnetic force theorem from the paramagnetic reference state [2]. This method is successfully applied to the TM3X Kagome magnet family (TM = Mn, Fe; X = Ga, Ge, Sn), demonstrating its computational efficiency and potential for high-throughput studies of unconventional non-collinear magnetic systems.

[1] M. T. Suzuki et al., Phys. Rev. B 95, 094406 (2017); [2] B. L. Gyorffy et al., J. Phys. F: Met. Phys. 15 1337 (1985).

MA 45.10 Fri 12:00 H18

Memory-Efficient Inverse Design for Advanced Magnonic Devices Using Level-Set Optimization — •Andrey Voronov[1,2], Marcos Cuervo Santos[2,3], Florian Bruckner[1,4], Dieter Suess[1,4], Andrii Chumak[1], and Claas Abert[1,4] — [1]Faculty of Physics, University of Vienna, Vienna, Austria — [2]Vienna Doctoral School in Physics, University of Vienna, Vienna, Austria — [3]Faculty of Sciences, University of Oviedo, Oviedo, Spain — [4]Research Platform MMM Mathematics - Magnetism - Materials, University of Vienna, Vienna, Austria

Inverse design in magnonics utilizes the wave nature of magnons and machine learning to develop logic devices with unique functionalities. However, existing methods face memory constraints, limiting the exploration of complex systems.

To address this, we integrate a level-set parameterization approach with an adjoint state method for memory-efficient simulations of magnetization dynamics. Implemented in neuralmag, a GPU-accelerated micromagnetic software, this framework enables efficient optimization of device topologies.

We validate the approach through two tasks: optimizing the shape of a magnetic nanoparticle to control hysteresis behavior and designing a 300-nm-wide yttrium iron garnet demultiplexer for frequency-selective spin-wave separation. These results showcase the algorithm's robustness and versatility in enabling the design of advanced magnonic devices for computational logic technologies.

MA 45.11 Fri 12:15 H18

Magnetoelectric coupling in type-I multiferroics via domain walls — •Aditya Putatunda and Sergey Artyukhin — Istituto Italiano di Tecnologia, Genova, Italy 16123

Type-I multiferroics, where ferroelectricity (FE) and magnetism arise independently with a large FE polarization but often tend to have a much weaker coupling to spins, e.g.: prototypical BiFeO3. Electric polarization, arising from inversion breaking, causes structural modifications across polarization domains in such materials. Here we demonstrate an effective coupling mechanism caused due to such structural modifications which in turn modifies the magnetic exchanges between the ions using first-principles density functional calculations. Magnetic domain walls, generally more mobile than polarization walls, depending on the nature of the materials, experience an effectively attractive or repulsive potential due to these modified exchanges. Such a potential can be taken advantage of in driving magnetic domain walls by sweeping polarization domains using electric field, thus giving rise to a cross-coupling mechanism, a highly sought phenomenon for novel low-power device applications.

MA 46: Surface Magnetism

Time: Friday 9:30–12:30 Location: H19

MA 46.1 Fri 9:30 H19

Investigation of the magnetic structure of Eu on W(110) — •Patrick Härtl[1], Vijayalaxmi Sankeshwar[1,2], Markus Leisegang[1], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Indian Institute of Science Education and Research(IISER), Pune, Maharashtra 411008, India

Rare earth metal (REM) films are renowned for their complex magnetic properties, primarily governed by the element-specific sign and wavelength of the RKKY interaction. Due to the complexity of their cleaning procedures, the magnetic domain structure of REM surfaces has remained largely unknown until today and is an ongoing topic of debate. In this study, we investigate the structural, electronic, as well as the complex magnetic structure of Europium (Eu) films on W(110) using spin-polarized scanning tunneling microscopy (SP-STM).

In the bulk, Eu has a half-filled $4f$- and an empty $5d$-shell and adopts a body-centered crystal structure. In thin epitaxial films, however, a metastable hexagonal close-packed structure is expected, accompanied by helical spin ordering below $T_{\text{Néel}} = 91\,\text{K}$. With optimal preparation conditions, we successfully grew clean, smooth films. In the tunneling spectra of these Eu films we observed two intense peaks at positive bias voltages which we interpret as the unoccupied and exchange-split $5d_{z^2}$-like surface state. Beyond a critical film thickness, striped regions with a periodicity of $\approx 3\,\text{nm}$ were identified. Experiments with differently magnetized STM tips and the application of an external magnetic field up to $\pm 2.5\,\text{T}$ revealed the magnetic nature of the stripes.

MA 46.2 Fri 9:45 H19

The magnetic domain structure of Ho(0001)/W(110) — •Vijayalaxmi Sankeshwar[1,2], Patrick Haertl[2], and Matthias Bode[2] — [1]Indian Institute of Science Education and Research (IISER), Pune, Maharashtra 411008, India — [2]Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Rare-earth metal (REM) films exhibit diverse magnetic phenomena driven by the indirect RKKY coupling of localized $4f$ orbital moments, which promotes the formation of helical spin structures. Holmium (Ho), notable for its exceptionally high magnetic moment ($\approx 10\,\mu_B$), develops stable helical configurations across a wide temperature range [1]. In its bulk form, Ho crystallizes in a hexagonal close-packed structure, transitioning from a helical spin spiral state below $T_N = 131\,\text{K}$ to a conical magnetic state below $T_C = 20\,\text{K}$. At reduced thicknesses, theoretical studies predict the emergence of intricate magnetic textures, including block spin structures [2].

We present an investigation of epitaxial Ho films grown on W(110) using spin-polarized scanning tunneling microscopy (SP-STM). Through a detailed, thickness-dependent analysis of the structural, electronic, and magnetic properties, we observed large in-plane magnetic domains spanning several hundred nanometers, interspersed with worm-like striped patterns exhibiting periodicities of $\approx 20\,\text{nm}$ in the magnetic signal. Our findings provide valuable insights into the relationship between dimensionality and magnetic order in REM films.

[1] D. L. Strandburg *et al.*, Phys. Rev. **127**, 2046 (1962)
[2] E. Weschke *et al.*, Phys. Rev. Lett. **93**, 157204 (2004)

MA 46.3 Fri 10:00 H19

Influence of higher order interactions on the thermal behaviour of magnetic order in Mn/Re(0001) — •Leo Kollwitz[1], Moritz Alexander Goerzen[2,1], Hendrik Schrautzer[3,1], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, Kiel University, 24098 Kiel, Germany — [2]CEMES, Université de Toulouse, CNRS, France — [3]Science Institute and Faculty of Physical Sciences, University of Iceland, 107 Reykjavík, Iceland

Non-trivial multi-Q states, which consist of the superposition of periodically modulated spin textures, are known to arise in Mn monolayers on the Re(0001) substrate due to higher-order exchange interactions (HOI) [1]. However, to date little is known about the thermodynamic properties of these highly ordered phases. Here, we perform Monte Carlo simulations based on an atomistic spin model parametrized by density functional theory, in order to investigate thermal phase transitions in this material. It is found that the explicit consideration of HOI in the simulations leads to a significant decrease of the Néel temperature and to an introduction of a new transition between single-Q and multi-Q states at low temperatures. Recent experiments show that a similar transition occurs in $Co_{1/3}TaS_2$ [2]. By modelling the free energy landscape of the system in terms of thermal excitations, which are expressed in the eigenbasis of the Hamiltonian, we further identify the important degrees of freedom responsible for this additional entropy mediated transition.

[1] J. Spethmann *et al*, Phys. Rev. Lett. **124**, 227203 (2020)
[2] P. Park *et al*, Nat. Comm. **14**, 8346 (2023)

MA 46.4 Fri 10:15 H19

Anisotropic magnetic exchange in a metal-organic interface with $4f$ electrons: the case of Cu Phthalocyanine on $HoAu_2$ and $GdAu_2$ — •María Blanco-Rey[1,2,3], Rodrigo Castrillo[3], Frederik M. Schiller[3,2], and Laura Fernández[3] — [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

Heterostructures formed by organic molecules on ferromagnetic substrates merge optoelectronic and spintronic functionalities. We have studied CuPc molecules deposited on monolayer-thick $REAu_2$ (RE=Ho, Gd) alloys, which exhibit long-range commensurability and vacuum level pinning of the LUMO. Many-body electron interactions renormalize the molecular levels. Here trivalent Ho and Gd species favour a downward shift of the HOMO, approaching ambipolarity [1]. The Curie temperatures are reduced from $\sim 20\,\mathrm{K}$ to $\sim 15\,\mathrm{K}$ due to CuPc, as the hybrid interfacial electronic structure affects the RKKY-mediated RE-RE exchange. The spin-orbit coupling of the RE leads to a dependence of the CuPc-RE antiferromagnetic exchange coupling constant $\mathcal{J}_{ex}$ on the field orientation, following the orbitally-dependent exchange (ODE) mechanism. ODE is enhanced by the large $L = 6$ value of trivalent Ho, yielding a ratio $\mathcal{J}_{ex}^{\parallel}/\mathcal{J}_{ex}^{\perp} = 4.2$, while the anisotropy is weak in the presence of Gd, with a half-field $4f$ shell [2].

[1] R. Castrillo et al, Nanoscale, 15, 4090 (2023).
[2] M. Blanco-Rey et al, Small, 20, 2402328 (2024).

MA 46.5 Fri 10:30 H19

Excitons design via topological spin-textures — •Karim Rezouali[1,2] and Samir Lounis[2,1] — [1]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Excitons are at the heart of many photonic and optoelectronic phenomena, including luminescence, lasing, and the operation of solar cells. Their study is essential for developing next-generation technologies, such as light-harvesting systems and quantum information devices. Here, we explore the impact of topological magnetism [1] on excitons by unveiling signatures of topology on the magnetic properties of excitons, their stability and manipulation. We address in particular skyrmions emerging in Pd/Fe/Ir(111) [2] surface, which affect the singlet and triplet exciton states hosted by a monolayer MoS_2 [3]. Our work promotes the use of skyrmions for the control and manipulation of excitons, which provides unprecedented opportunities for exciton-based devices.

[1] M. V. Berry, Proc. R. Soc. Lond. A 392, 45 (1984).
[2] N. Romming, A. Kubetzka, C. Hanneken, K. von Bergmann, and R. Wiesendanger, Phys. Rev. Lett. 114, 177203 (2015)
[3] M. Palummo, M. Bernardi, and J. C. Grossman, Nano Letters 15, 2794 (2015).

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

MA 46.6 Fri 10:45 H19

Observation of the sliding phason mode of the incommensurate magnetic texture in Fe/Ir(111) — •Wulf Wulfhekel[1], Hung-Hsiang Yang[1], Louise Desplat[2], Volodymyr Kravchuk[1], Marie Hervé[1], Timofey Balashov[1], Simon Gerber[1], Markus Garst[1], and Bertrand Dupé[2] — [1]Karlsruhe Institute of Technology — [2]Université de Liège

The nanoscopic magnetic texture forming in a monolayer Fe/Ir(111) is uniaxially incommensurate with respect to the Ir(111) substrate. As a consequence, a low-energy magnetic excitation is expected that corresponds to the sliding of the texture along the incommensurate direction, i.e., a phason mode, that we confirm with atomistic spin simulations. Using Sp-STM, we observed this phason mode experimentally. It can be excited by the STM tip leading to a random telegraph noise in the tunneling current that we attribute to the presence of two minima in the phason potential due to the presence of disorder in the sample. This provides the prospect of a floating phase in cleaner samples and, potentially, a commensurate-incommensurate transition as a function of external control parameters.

15 min. break

MA 46.7 Fri 11:15 H19

Quantifying the interplay between local order and dynamics in a self-induced spin glass — •Lorena Niggli[1], Julian H. Strik[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 characterized by an amorphous spin texture in space. They exhibit ongoing magnetization dynamics that are often referred to as aging. However, direct experimental access to the spatially dependent magnetization and its link to aging, has been limited. Here, we study the spatiotemporal dy- namics of the self-induced spin glass state of Nd(0001) [1, 2]. To this end, we induce magnetization dynamics through magnetic field cycles and resolve the local order using spin-polarized scanning tunneling microscopy. We develop a new method to access the spatiotemporal dynamics based on a wavelet transformation. Using this, we quantify the Q-dependent local order in space and follow its evolution over time. Together this provides insight into the complex energy landscape of a (self-induced) spin glass. [1] Kamber et al., Science 368 (2020). [2] Verlhac et al., Nature Physics 18 (2022).

MA 46.8 Fri 11:30 H19

Bilayer triple-Q state driven by interlayer higher-order exchange interactions — •Bjarne Beyer, Mara Gutzeit, Tim Drevelow, Isabel Schwermer, Soumyajyoti Haldar, 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 only recently observed in Mn monolayers on the Re(0001) surface [2,3]. Here, we predict a triple-Q state as the magnetic ground state of a Mn bilayer on the Ir(111) surface using first-principles calculations based on density functional theory (DFT). In a bilayer two types of the triple-Q state can occur which differ by the spin alignment between the layers. Based on an atomistic spin model, we demonstrate that the triple-Q state favored by DFT is stabilized by the interplay of antiferromagnetic interlayer exchange and interlayer higher-order exchange interactions. In this bilayer triple-Q state nearest-neighbor spins within a layer and between layers exhibit tetrahedron angles and the topological orbital moments of the two Mn layers are aligned in parallel [4].

[1] P. Kurz *et al.*, PRL **86**, 1106 (2001).
[2] J. Spethmann *et al.*, PRL **124**, 227203 (2020).
[3] F. Nickel *et al.*, PRB **108**, L180411 (2023).
[4] V. Saxena *et al.*, arXiv:2408.12580 (2024).

MA 46.9 Fri 11:45 H19

Antiferromagnetic merons in a Mn monolayer on Ta(110) — •Tim Drevelow[1], Felix Zahner[2], André Kubetzka[2], Roland Wiesendanger[2], Stefan Heinze[1], and Kirsten von Bergmann[2] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany — [2]Department of Physics, University of Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

Non-collinear topological spin structures in ultrathin transition-metal films are interesting for spintronic applications. When hosted in antiferromagnets, they are robust to external perturbations, possess vanishing demagnetization fields, and the Skyrmion-Hall effect does not occur. Ultrathin Mn-layers are intrinsically antiferromagnetic and exhibit non-collinear spin structures, such as the conical spin structure in Mn on W(110) [1]. Here, using spin-polarized scanning tunneling microscopy and density functional theory, we discover a cycloidal spin spiral and a $c(2 \times 2)$ antiferromagnet in Mn mono- and double-layers on the Ta(110) surface, respectively. Micromagnetic simulations on the sublattice reveal a transition of spin spirals into antiferromagnetic, meronic spin structures of non-trivial topology near the interface to the collinear antiferromagnet of the film due to competing anisotropies of the Mn mono- and double-layer.

[1] Yoshida *et al.* Phys. Rev. Lett. **108**, 087205 (2012)

MA 46.10 Fri 12:00 H19

Magnetic bi-stability of columnar Transition-metal-oxide molecules on MgO films — •SUFYAN SHEHADA[1,2], Manuel dos Santos Dias[3], Muayad Abusaa[2], and Samir Lounis[1,4] — [1]Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, 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 and CENIDE, 47053 Duisburg, Germany

At the heart of quantum information technology is the realization of stable atomic magnetic bits, which partly hinges on large out-of-plane magnetic anisotropy energy (MAE). Although the seminal work of Rau et al.[1] reported the maximum MAE for a 3d element by positioning a Co atom on MgO(100) [1], the system did not exhibit magnetic bi-stability. Motivated by that work, we explore via density functional theory (DFT) simulations columnar oxide molecules made of transition metals (TM-O), which might show large MAE while reducing the hybridization of the adatoms' electronic states with those of the substrate, increasing the chances of magnetic bi-stability. Following our initial investigations based on 3d elements [2], we address here the case of 4d atoms and focus on the scenario where the TM atoms are decoupled from the surface via an Oxygen atom.

–Work funded by (BMBF–01DH16027).

[1] Rau *et al.*, Science **344**, 988 (2014). [2] Shehada *et al.*, ArXiv:2403.05432, accepted in PRB (2024).

MA 46.11 Fri 12:15 H19

Tailoring magnetism in a 2D Van der Waals material with a chemical approach for magnonic applications — •Sourav Dey, Gonzalo Rivero, and José Baldoví — ICMol, University of Valencia, Valencia, Spain

The discovery of two-dimensional (2D) magnets offers an ideal platform for magnonics and spintronics at the limit of miniaturization given their high flexibility and tunability.The magnetic properties of this family of materials have been tuned by several approaches such as strain engineering, atomic layer substitution, or molecular deposition, among others. In the latter case, the effect of organometallic/inorganic complexes on the magnetic properties of 2D magnetic materials is still unexplored. To investigate this, we have selected two molecular qubits (quantum bits) with long coherence time such as CpTiCOT (Cp = η5-cyclopentadienyl, COT = η8-cyclooctatetraene) and VOPc (Pc = phthalocyanine) which are proved to be stable after the deposition on metallic substrate. Here, we analyze and interpret the magnetic properties of single-layer CrSBr after deposition of CpTiCOT and VOPc, via first-principles calculations. Our results predict a significant modulation of magnetic exchange in CrSBr after deposition due to the significant charge transfer from the molecules to 2D material, allowing us to corroborate both properties. Furthermore, a significant change in the magnon frequencies and group velocities was observed, which opened new avenues in designing smart molecular/2D materials where magnons can be fine-tuned by a chemical approach.

MA 47: Altermagnets III

Time: Friday 9:30–11:00 Location: H20

MA 47.1 Fri 9:30 H20

Growth and spectroscopy of altermagnetic MnTe — •Marco Dittmar, Lena Hirnet, Hannes Haberkamm, Maximilian Ünzelmann, and Friedrich Reinert — Exp. Physik VII and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Germany

As a new type of fundamental magnetic order next to ferro- and antiferromagnetism, altermagnetism has recently attracted great attention [1]. It is characterized by antiferromagnetic spin alignment combined with rotational lattice symmetry, which results in a momentum-dependent spin-split band structure with spin polarized electronic states. One of the "workhorse" materials potentially exhibiting this type of magnetic order is MnTe in its hexagonal NiAs-type crystal structure [1,2]. Here, we investigate MnTe thin films grown by molecular beam epitaxy. The high film quality is confirmed by structural characterization methods, while we assess the three-dimensional bulk band structure using soft X-ray angle-resolved photoemission spectroscopy. The experimentally observed spectral features agree well with band structure calculations and — based on that — the possible occurance of the characteristic momentum-dependent spin splitting will be discussed.

[1] L. Šmejkal *et al.*, Phys. Rev. X **12**, 031042 (2022)
[2] J. Krempaský *et al.*, *Nature* **626**, 517-522 (2024)

MA 47.2 Fri 9:45 H20

Phonon-mediated unconventional superconductivity in altermagnets: A solid-state analog of the A_1 phase of superfluid Helium 3 — •Kristoffer Leraand[1], Kristian Maeland[2], and Asle Sudbø[1] — [1]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [2]Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We have considered the possibility of phonon-mediated unconventional superconductivity in a recently discovered new class of antiferromagnets, dubbed altermagnets. Within a weak-coupling approach, and using a minimal band model for altermagnets [1], we have found a dominant superconducting instability odd in momentum and even in spin with fully spin-polarized Cooper pairs, a 2D solid-state analog of the A_1-phase of superfluid Helium 3 [2]. We discuss the origin of this unusual result in terms of phonon-modes and electron form factors. [1] B. Brekke, A. Brataas, and A. Sudbø, PRB 108, 224421 (2023). [2] G. Volovik, The Universe in a Helium Droplet, Oxford Science Publications (2003). Work supported by Norwegian Research Council, through Grant No. 262633, "Center of Excellence on Quantum Spintronics", as well as Grant No. 323766.

MA 47.3 Fri 10:00 H20

Non-linear anomalous Edelstein response at altermagnetic interfaces — •Mattia Trama[1,2], Irene Gaiardoni[3], Claudio Guarcello[3,4], Jorge I. Facio[5], Alfonso Maiellaro[3,6], Francesco Romeo[3,4], Roberta Citro[3,4,6], and Jeroen van den Brink[1,2] — [1]IFW Dresden — [2]Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Università degli studi di Salerno — [4]INFN - Sezione collegata di Salerno — [5]Centro Atomico Bariloche, Instituto de Nanociencia y Nanotecnologia (CNEA-CONICET) and Instituto Balseiro — [6]CNR-SPIN

In altermagnets, time-reversal symmetry breaking spin-polarizes electronic states, while total magnetization remains zero. In addition, at altermagnetic surfaces Rashba-spin orbit coupling is activated due to broken inversion symmetry, introducing a competing spin-momentum locking interaction. Here we show that their interplay leads to the formation of complex, chiral spin textures that offer novel, non-linear spin-to-charge conversion properties. Whereas altermagnetic order suppresses the canonical linear in-plane Rashba-Edelstein response, we establish the presence of an anomalous transversal Edelstein effect for planar applied electric and magnetic field, or alternatively, an in-plane magnetization. Moreover the non-linear Edelstein response resulting purely from electric fields also triggers the anomalous out-of-plane magnetization. We determine the anomalous response with a model based on the ab-initio electronic structure of RuO2 bilayers, ultimately opening experimental avenues to explore spin-charge conversion phenomena at altermagnetic interfaces.

MA 47.4 Fri 10:15 H20

A Heisenberg model for g-wave altermagnets: the comparative analysis of CrSb and MnTe — •Volodymyr Kravchuk[1,2], Kostiantyn Yershov[1,2], Oleg Janson[1], and Jeroen van den Brink[1] — [1]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, 03143 Kyiv, Ukraine

Here we construct a discrete Hamiltonian of the magnetic subsystem of altermagnets belonging to the crystallographic group $6/mmm$. The altermagnetic properties are captured through the additional Heisenberg exchange interactions whose symmetry respects the positions of the nonmagnetic atoms. We derive the dispersion relation for magnons for two opposite cases of magnetocrystalline anisotropy: easy-axis (as for CrSb) and easy-plane (as for MnTe). Due to the different magnetic ground states of CrSb and MnTe, their magnon spectra are drastically different. While the splitting of the magnon bands of CrSb possesses the g-wave symmetry, the splitting of the magnon bands of MnTe does not alternate sign within the Brillouin zone and does not possess g-wave symmetry. We formulate the continuous approximation of the model and derive the expression for magnetization of the noncollinear magnetization structures. We find that the amplitude of the magnetization of a domain wall in CrSb depends on the domain wall orientation relative to crystallographic axes, and determine twelve orientations that correspond to the maximal magnetization.

MA 47.5 Fri 10:30 H20

P-wave magnetism and spin symmetries — •Anna Birk Hellenes[1], Tomáš Jungwirth[2,3], Rodrigo Jaeschke-Ubiergo[1], Atasi Chakraborty[1], Jairo Sinova[1,4], and Libor Smejkal[1,2,5,6] — [1]JGU Mainz — [2]Czech Academy of Sciences — [3]University of Nottingham — [4]Texas A&M University — [5]MPI-PKS — [6]MPI-CPfS

The recent discovery of altermagnets was enabled by an unorthodox symmetry toolbox, crystallographic spin groups, allowing for the rigorous delineation of all collinear spontaneous exchange symmetry breakings. This raises a question: are further magnets with hitherto unknown symmetries and electronic structures hiding in plain sight? Our contribution will start with a brief history of a century-long debate on whether p-wave magnetic orders can exist. We will resolve this debate by demonstrating p-wave magnetism using the spin group formalism. We show that a collinear p-wave order arises in coplanar magnets for a subclass of noncentrosymmetric, noncollinear magnets with a combined translation and time-reversal symmetry. Contrary to common assumptions, we establish that such magnets can display non-relativistic spin-split electronic band structures. We demonstrate that these splittings preserve time-reversal symmetry, starkly contrasting splittings in ferromagnets and altermagnets, which break it. With first-principles calculations and symmetry analysis, we predict large, non-relativistic spin-splittings of several hundred meV and identify more than 40 realistic material candidates. Our work opens a wide range of possibilities for studying p-wave magnetism and using it for spintronics and topological physics. arXiv:2309.01607v3

MA 47.6 Fri 10:45 H20

Spin polarons in Altermagnets — •Maria Daghofer[1], Krzysztof Wohlfeld[2], and Jeroen van den Brink[3] — [1]FMQ, Universität Stuttgart, Stuttgart, Germany — [2]University of Warsaw, Warsaw, Poland — [3]IFW Dresden, Dresden, Germany

We numerically investigate hole motion in altermagnetic Mott insulators, beyond the weakly interacting case, where a mean-field description is applicable. In this strongly correlated regime, hole motion is strongly affected by coupling to quantum fluctuations of the magnetic background. We find that the underlying altermagnetic symmetries manifest themselves in spin-momentum locking of the coherent quasiparticle: At certain momenta, it has a spin-polarized character, while states corresponding to the opposite spin are considerably more incoherent. We also address the impact of quantum fluctuations.

MA 48: Ultrafast Magnetization Effects II

Time: Friday 11:15–13:00 Location: H20

MA 48.1 Fri 11:15 H20

Measurement of time resolved magneto-optic Kerr effect on ruthenium dioxide — •Holger Grisk[1], Maik Gaerner[2], Jakob Walowski[1], Timo Kuschel[2], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald University, Germany — [2]Faculty of Physics, Bielefeld University, Germany

Altermagnetism is a novel fundamental phase of magnetism with exciting properties such as spin split bands.Ruthenium dioxide is one of the mostly investigated altermagnetic candidates. The antiparallel alignment of the Ru spins along with the anisotropic distribution of oxygen atoms leads to time reversal symmetry breaking and non-relativistic, anisotropic spin-splitting in the band structure. We used the time-resolved magneto-optic Kerr effect to measure the transient Kerr angle and reflectivity change after excitation with a femtosecond laser pulse to access the potential magnetic properties of ruthenium dioxide. The setup for the measurement exploits the pump-probe technique. A femtosecond laser pulse is split into a powerful pump and a low-power probe beam. The pump beam is used to photoexcite the electrons in the ruthenium dioxide. The probe beam is used to measure the shift in the Kerr rotation. Delaying the pump temporally and probing the evolution of the Kerr signal we can measure the ultrafast spin dynamics of ruthenium dioxide. The measurement shows Terahertz dynamics in the Kerr signal that is an order of magnitude faster than conventional ferromagnets. The studies were performed at room temperature and with small in plane magnetic field.

MA 48.2 Fri 11:30 H20

Dynamical renormalization of the magnetic excitation spectrum via high-momentum nonlinear magnonics — •Julian Bär[1], Lennart Feuerer[1], Alfred Leitenstorfer[1], Dominik Juraschek[2], and Davide Bossini[1] — [1]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78464 Konstanz, Germany — [2]Department of Applied Physics and Science Education, Eindhoven University of Technology, Eindhoven, Netherlands

Manipulating the macroscopic properties of solids with light is a key challenge in condensed matter physics. While resonantly driving low-momentum collective excitations has led to nonlinear lattice and spin dynamics [1,2], controlling magnon spectra in terms of amplitude and frequency remains unexplored. In my talk I will discuss the resonant excitation of pairs of high-momentum magnons in Hematite (α-Fe2O3). By exciting hematite in its weak-ferromagnetic phase, our approach results in a direct coupling between high- and low-momentum magnons. In particular, the spectrum of the latter is modified. This astonishing effect is explained with a resonant light-scattering mechanism that couples high- and low-momentum eigenmodes across momentum space [3]. As hematite undergoes a phase transition at 260 K to a collinear antiferromagnetic state, we have developed a cryogenic pump-probe setup. Preliminary results reveal behaviour distinct from that observed in the weak ferromagnetic phase. [1] A. S. Disa et al., Nat Phys 17, 1087-1092 (2021). [2] Z. Zhang et al., Nat Phys., 1-6 (2024). [3] C. Schoenfeld et al., arXiv:2310.19667 (2024)

MA 48.3 Fri 11:45 H20

Bias field studies of all-optical helicity-dependent switching. — •Kevin Jäckel[1], Marcel Kohlmann[1], Jakob Walowski[1], Markus Münzenberg[1], Yuta Sasaki[2], and Karel Carva[3] — [1]University of Greifswald, Germany — [2]Research Center for Magnetic and Spintronic Materials, Japan — [3]Charles University, Czech Republic

The mechanisms underlying all-optical helicity-dependent switching AOHDS need a better understanding to improve the process towards single pulse switching. We apply external magnetic fields (anti-) parallel of up to $H_{\text{ext}} = 72\,\text{mT}$, (opposing) supporting the desired magnetization direction in FePt granular media to disentangle the contribution of the inverse Faraday effect IFE within the switching process. Those measurements, performed on samples with varying average grain size diameters of $d = 10\,\text{nm}$, $d = 6\,\text{nm}$ nm, and $d = 4\,\text{nm}$, reveal a grain size dependent impact of the applied field strength. Using the helicity-dependent refractive index calculated from density functional theory (DFT) calculations, we calculate the absorbed laser fluence for each grain size using the transfer matrix method. The absorption data, combined with the inverse Faraday constant, allows us to quantify the optically induced magnetization ΔM by the IFE. From this data, we can estimate the contribution of the IFE to the switching process. The research is funded by DFG, Fundamental aspects of all-optical pulse switching in nanometer-sized magnetic storage media Project number: 439225584.

MA 48.4 Fri 12:00 H20

Terahertz study of antiferromagnetic resonance in α MnTe — •Michal Šindler[1], Roman Tesař[1], Karel Výborný[1], Stáňa Tazlerů[1], Christelle Kadlec[1], Peter Kubaščík[2], Lukáš Nádvorník[2], Marcin Bialek[3], Jan Dzian[2,4], and Milan Orlita[4] — [1]Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic — [3]Institute of High Pressure Physics Polish Academy of Sciences, Warszawa, Poland — [4]Laboratoire National des Champs Magnétiques Intenses, Université Grenoble Alpes, CNRS-UPS-INSA-EMFL, Grenoble, France

Antiferromagnetic resonance in bulk α-MnTe crystal was studied in the terahertz (THz) range. First, we will describe the three experimental methods used: (i) infrared Fourier transform spectroscopy,(ii) time-domain THz spectroscopy, and (iii) frequency-domain terahertz

spectroscopy with linearly and circularly polarized THz beams. Second, we will present experimental results featuring a magnon mode ($k = 0$) with the low-temperature energy of 3.5 meV and its temperature and magnetic field evolution. Finally, we will show how to extract the out-of-plane component of the single-ion magnetic anisotropy $D \approx 40\,\mu$eV using a simple spin model of antiferromagnetic resonance in an easy-plane antiferromagnet.

MA 48.5 Fri 12:15 H20

Indications of terahertz spin transport in the altermagnet candidate RuO2 — •Oliver Gueckstock[1], Clara Simons[1], Maik Gaerner[2], Zdenek Kaspar[3], Jiri Jechumtal[3], Tom S. Seifert[1], Lukas Nadvornik[3], Günter Reiss[2], and Tobias Kampfrath[1] — [1]FU Berlin — [2]U Bielefeld — [3]Charles University Prague

The recently emerging material class of altermagnets has large potential to offer properties like strong spin splitting, which are so far rather typical for classical ferromagnets [1]. RuO2 appears to be a promising metallic altermagnet candidate with huge spin splitting in the electronic band structure and for photoinduced spin and orbital transport with a Néel temperature above room temperature [1,2]. Here, we apply femtosecond laser pulses to RuO2(110)|HM stacks consisting of a twinned RuO2 layer and a heavy-metal layer HM of Pt or W. We observe THz emission signals with distinct pump-polarization dependence. The signals change sign when HM=Pt is replaced by W and exhibit a marked temperature dependence, thereby suggesting a magnetism-related signal origin. We discuss possible mechanisms of THz-signal generation, including an ultrafast photoinduced spin current from RuO2 to HM and its conversion into in-plane charge in HM, which gives rise to the emission of a THz electromagnetic pulse. References: [1] Smejkal et al., Phys Rev. X 12, 040501 (2022), [2] Adamantopoulos et al., npj spintronics 2, 46 (2024)

MA 48.6 Fri 12:30 H20

THz emission control in exchange-coupled spintronic emitters. — •Roman Adam[1], Derang Cao[1,2], Daniel Bürgler[1], Sarah Heidtfeld[1], Christian Greb[1], Fangzhou Wang[1], Debamitra Chakraborty[3], Jing Cheng[3], Ivan Komissarov[3], Markus Büscher[1], Martin Mikulics[4], Hilde Hardtdegen[4], Roman Sobolewski[3], and Claus Schneider[1] — [1]Research Centre Jülich, Peter Grünberg Institute (PGI-6), 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China — [3]University of Rochester, Rochester, New York 14627-0231, USA — [4]Research Centre Jülich, Ernst Ruska Centre (ERC-2), 52425 Jülich, Germany

Optical laser pulses impinging at the ferromagnet/metal thin film stacks can generate a pico-second electro-magnetic transients with frequency content extending into THz frequency range. We fabricated Si/SiO2//Ta/Fe/Ru/Ni/Al2O3 and Si/SiO2//Pt/Fe/Cr/Fe/Pt spintronic THz emitters in which we varied interlayer exchange coupling between the ferromagnetic thin films by varying the thicknesses of either the Ru or Cr spacer layer. As a result, THz emission shows a dramatic variation of amplitude in weak external magnetic fields due to an interference of THz transiens generated at the individual Fe/Ru, Ru/Ni or Fe/Pt emitters. We explore the effect of the ambient temperature and the spacer layer thickness variations on the THz amplitude.

MA 48.7 Fri 12:45 H20

On-Chip Multilayer Spintronic THz Emitters — •Wolfgang Hoppe[1], Amine Wahada[2], Stuart Parkin[3], and Georg Woltersdorf[1] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Department of Physical Chemistry, Fritz Haber Institute, Faradayweg 4-6, 14195 Berlin, Germany — [3]Max Planck Institute for Microstructured Physics, Weinberg 2, 06120 Halle, Germany

Nanometer thin ferromagnet/heavy metal bilayers illuminated by intense short laser pulses have proven to be a realiable source for THz emission [1]. When integrated into a gold waveguide structure, the bilayer can be used as an on-chip source for ultrafast current pulses from the GHz to the THz regime [2]. Stacking severeral bilayers, each separated by a thin MgO interlayer enhances the charge current amplitude, as the MgO suppresses spin-currents in between the individual bilayers [3]. In this way we construct multilayers where all charge currents add up constructively, enhancing the signal up to a factor of three. As one possible application these ultrafast currents could be used to switch the magnetization of an adjacent ferromagnet, similar to previous experiments [4]. Electro-optic sampling is employed to characterize the charge current with sub-ps time resolution.

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