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 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 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 nonmagnetic (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-μT/$\sqrt{\text{Hz}}$ range within a field of view (FOV) of approximately $60 \times 60\,\mu\text{m}^2$, 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 $3d$-$4f$ 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.