MA 23: Poster Magnetism I

Skyrmions (MA 23.1-23.13), Non-Skyrmionic Magnetic Textures (MA 23.14-23.15), Caloric Effects in Ferromagnetic Materials (MA 23.16-23.19), Molecular Magnetism (MA 23.20-23.25), Biomagnetism, Biomedical Applications (MA 23.26-23.28), Electron Theory of Magnetism and Correlations (MA 23.29-23.33), Magnetic Imaging Techniques (MA 23.34-23.43), Neuromorphic Magnetism / Magnetic Logic (MA 23.44), Computational Magnetism (MA 23.45-23.49), Spin Transport and Orbitronics, Spin-Hall Effects (MA 23.50-23.53), Terahertz Spintronics (MA 23.54-23.56), Spin-Dependent Phenomena in 2D (MA 23.57-23.58), Spintronics (other effects) (MA 23.59-23.62), Functional Antiferromagnetism (MA 23.63-23.65), Magnonics (MA 23.66-23.80)

Time: Tuesday 17:00–19:00 Location: P1

MA 23.1 Tue 17:00 P1

Lattice effects of the skyrmion compound $SrFeO_3$ in high magnetic fields — •Mathias Doerr[1], Nikita Andryushin[1], Clara Ebersbach[1], Sergey Granovsky[1], Darren Peets[1], Yuri Skourski[2], and Dmitro Inosov[1] — [1]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Germany

The magnetic properties of the cubic perovskites ABO_3 (A = alkalis, B = transition metal, *e.g.* Mn, Fe, Co) strongly depend on lattice variations. In particular, the magnetoelastic properties of $SrFeO_3$, which is characterised by a variation of topological helical spin structures with the formation of skymions, were investigated in steady and pulsed magnetic fields up to 50 T. Magnetostriction measurements in longitudinal and transversal geometry confirmed lattice distortions in the order of 10^{-5} only occur in the domain-selection processes, in these cases with an irreversible character. Other magnetic phase transitions are not triggered by lattice effects. Based on the new data, the (H, T) phase diagram could be refined and supplemented. At the same time, the results show fundamental differences to other perovskites containing Mn or Co on the B-site.

MA 23.2 Tue 17:00 P1

Asymmetric skyrmion flow in a periodically modulated channel — •Klaus Raab[1], Maarten A. Brems[1], Maurice Schmidt[1], Jan Rothörl[1], Fabian Kammerbauer[1], Peter Virnau[1], and Mathias Kläui[1,2] — [1]1Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]2Graduate School of Excellence Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

We investigate the non-equilibrium flow behavior of skyrmions driven by spin-torques in complex channel geometries and construct functional building blocks for targeted manipulation of skyrmion flow. Poiseuille-like velocity flow-profiles usually occur due to no-slip boundary conditions, meaning moving particles do interfere with the boundary e.g. the wall of a geometry, reducing the velocity of particles closer to a wall. Skyrmions on the other hand should experience slip at the boundaries du to the repulsive nature of the skyrmion-edge and skyrmion-skyrmion interaction. Adding structured obstacles along the boundary may lead to partial or even no-slip behavior and thus to Poiseuille-like flow profiles while skyrmions are forced through a wire due to spin-torques. Selected edge shapes (sawtooth, triangles, ...) and the periodicity and amplitude of the modulation of the wire width influencing the flow were optimized and tested using simulations. Understanding flow dynamics and velocity profiles of skyrmions, their interaction with each other and their harboring geometry is essential for skyrmionic applications like the racetrack memory.

MA 23.3 Tue 17:00 P1

Time-Multiplexed Reservoir Computing with Skyrmions — •Grischa Beneke[1], Thomas Winkler[1], Maarten A. Brems[1], Klaus Raab[1], Fabian Kammerbauer[1], Johan H. Mentink[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Institute for Molecules and Materials, Radboud University, The Netherlands

Reservoir computing (RC) is a key method for significantly reducing the computational effort of complex tasks like pattern recognition [1]. Magnetic skyrmions, topological particle-like spin textures, are very promising candidates for RC systems given their non-linear interactions and a multitude of established mechanisms for skyrmion manipulation. By exploiting the thermally activated diffusive motion of skyrmions [2] and an automatic reset mechanism enabled by the repulsion of skyrmions form the boundaries of the magnetic materials, we have previously realized spatially multiplexed RC using a single skyrmion [3]. Here, we employ time-resolved inputs, exploiting the electrically gated skyrmion motion and use the time-dependent state of our device as an output mechanism [4]. We experimentally demonstrate that already a minimalistic device suffices to perform linearly non-separable logic operations. Increasing the complexity of the device using multiple skyrmions or an interplay of multiple devices, may pave the way for low-power and low-training classification of real-life data.

[1] D. Gauthier et al., Nat. Comms. 12, 5564 (2021). [2] J. Zázvorka et al., Nat. Nanotechnol. 14, 658 (2019). [3] K. Raab et al., Nat. Comms. 13, 6982 (2022). [4] G. Beneke et al., in preparation (2022).

MA 23.4 Tue 17:00 P1

Skyrmionic spin structures in layered Fe5GeTe2 up to room temperature — •Maurice Schmitt[1], Thibaud Denneulin[2], András Kovács[2], Tom Saunderson[1,3], Philipp Rüssmann[3,4], Aga Shahee[1], Tanja Scholz[5], Amir Tavabi[2], Martin Gradhand[1,6], Phivos Mavropoulos[7], Bettina Lotsch[5,8], Rafal Dunin-Borkowski[2], Yuriy Mokrousov[1,3], Stefan Blügel[3], and Mathias Kläui[1,9] — [1]JGU Mainz — [2]Ernst Ruska-Centre, Jülich — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Jülich — [4]University of Würzburg — [5]Max Planck Institute for Solid State Research, Stuttgart — [6]University of Bristol — [7]University of Athens — [8]LMU, München — [9]NTNU, Trondheim

The role of the crystal lattice, temperature and magnetic field for the spin structure formation in the 2D van der Waals magnet Fe5GeTe2 with magnetic ordering up to room temperature is a key open question. Using Lorentz transmission electron microscopy, we experimentally observe topological spin structures up to room temperature in the metastable pre-cooling and stable post-cooling phase of Fe5GeTe2. Over wide temperature and field ranges, skyrmionic magnetic bubbles form without preferred chirality, which is indicative of centrosymmetry. These skyrmions can be observed even in the absence of external fields. To understand the complex magnetic order in Fe5GeTe2, we compare macroscopic magnetometry characterization results with microscopic density functional theory and spin-model calculations. Our results show that even up to room temperature, topological spin structures can be stabilized in centrosymmetric van der Waals magnets.

MA 23.5 Tue 17:00 P1

Enhanced diffusion of antiferromagnetically coupled skyrmions — Takaaki Dohi[1], Markus Weissenhofer[2], Nico Kerber[1], Fabian Kammerbauer[1], •Maria-Andromachi Syskaki[1], Gerhard Jakob[1], Ulrich Nowak[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Fachbereich Physik, Universität Konstanz, DE-78457 Konstanz, Germany

Magnetic skyrmions are attractive for the intriguing responses governed by their topology [1]. However, some of the topology-dependent features of magnetic skyrmions are recognized as an obstacle to device applications, e.g. the skyrmion Hall effect [2], which however does not occur in antiferromagnetic skyrmions. Here we demonstrate that a synthetic antiferromagnetic (SyAFM) system [3] with low pinning enables thermally-activated diffusive motion of antiferromagnetically-coupled skyrmions. The systematic investigation varying the compensation ratio of magnetic moments in the magnetic sub-lattices with our analysis accounting for pinning effects allows for disentangling the influence of the topology on the diffusive motion. Our analysis reveals an at least 10 times larger diffusion coefficient for highly compensated antiferromagnetically-coupled skyrmions that is a direct consequence of the reduction of the effective topological charge, which enables energy-efficient unconventional computing. [1] N. Nagaosa and Y. Tokura, Nat. Nanotechnol. 8, 899 (2013). [2] K. Litzius et al., Nat. Phys. 13, 170 (2017). [3] T. Dohi et al., Nat. Commun. 10, 5153 (2019).

MA 23.6 Tue 17:00 P1

Thermal skyrmion diffusion with alternating current excitations — •Tobias Sparmann, Raphael Gruber, Jan Rothörl, Maarten A. Brems, Fabian Kammerbauer, and Mathias Kläui — Department of Physics, Johannes-Gutenberg University Mainz

Magnetic skyrmions are considered promising candidates for implementing probabilistic computing devices since they respond strongly nonlinearly to external stimuli and feature multiscale dynamics [1].

The implementation of such probabilistic computing relies on thermal excitation and diffusive movement of the magnetic skyrmions within thin films, which exhibit pinning due to sample defects [2]. Especially the combination of skyrmion diffusion and current-induced motion has been shown to be useful in Brownian reservoir computing devices [3]. As thermal skyrmion diffusion is often slow due to the impact of pinning, a depinning procedure using the already present electric excitation of the skyrmions can be key for applications.

To reach such a regime of very high diffusion, we propose and experimentally demonstrate depinning by applying alternating currents to the sample [4]. In particular, we show that the energy landscape is effectively flattened and diffusion drastically enhanced for sufficient current densities. This can therefore be useful to reduce pinning effects and accelerate non-conventional computing devices.

[1] D. Prychynenko et al., Phys. Rev. Applied, 9, 014034 (2018).
[2] J. Zázvorka et al., Nat. Nanotechnol., 14, 658 (2019).
[3] R. Gruber et al., Nat. Comm., 13, 3144 (2022).
[4] T. Sparmann et al., in preparation (2022).

MA 23.7 Tue 17:00 P1

Current driven skyrmion movement and their electrical detection in Ta/CoFeB/MgO — •Hauke Lars Heyen[1], Malte Römer-Stumm[2], Jakob Walowski[1], Christian Denker[1], Kornel Richter[2], Jeffey McCord[2], and Markus Münzenberg[1] — [1]Institute of Physics, University of Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [2]Christian-Albrechts-University in Kiel, Institute for Materials Science, Nanoscale Magnetic Materials and Magnetic Domains, 24143 Kiel, Germany

Magnetic skyrmions, the two-dimensional topological protected round spin structures, have a strong potential for implementation into future storage devices as information bits e.g., in the conceptual racetrack memory. For this purpose, the dynamics of skyrmion motion and their detection is an essential tool. Skyrmions can be generated in Ta/CoFeB/MgO layer stacks at room temperature. Using current pulses in the nanosecond range, it is possible to move the skyrmions with current densities of 10^12 - 10^13 A/m^2. The dynamic trajectories hint to the skyrmion-Hall-effect and superdiffusion, requiring special racetrack design. The skyrmion-Hall-effect results from the skyrmion topology and the superdiffusion occurs due to defects on the motion path. Magnetic tunnel junctions (MTJ) are a promising tool to detect small magnetization changes. The selected Ta/CoFeB/MgO material system allows to build MTJs into skyrmion samples. But this integration of MTJs remains challenging, even though they work fine independently.

MA 23.8 Tue 17:00 P1

Design of an rf antenna for fast skyrmion lattice relaxation — •Ephraim Spindler[1], Philipp Schwenke[1], Abbass Hamadeh[1], Raphael Gruber[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

Understanding skyrmion dynamics is a key requirement for their potential applications in data storage and processing. We designed an omega-type microwave antenna to study the lattice formation dynamics of micrometer-scale skyrmions in thin film materials under rf excitation. We evaluated the antenna performance by measuring its electrical transmission and the magnetic field generated by dc current flow through the antenna. To quantify the rf performance of the antenna further, we used it for ferromagnetic resonance (FMR) measurements on reference thin-film $Y_3Fe_5O_{12}$ samples. From our power-dependent FMR measurements we determined the microwave power of the transition to the nonlinear regime. The microwave power threshholds are compared to expectations from micromagnetic simulations considering the inhomogeneous rf field profile of the antenna. These power-dependent measurements and simulations allowed us to quantify the rf fields generated by the antenna. The rf fields generated by the omega antenna can potentially accelerate the skyrmion lattice relaxation through its direct influence on skyrmion size oscillations.

MA 23.9 Tue 17:00 P1

Influence of lattice strain on possible skyrmions in $SrRuO_3$-based oxide heterostructures — •Robert Gruhl, Ludwig Scheuchenpflug, and Philipp Gegenwart — Experimentalphysik VI, Universität Augsburg, 86159 Augsburg, Germany

Dzyaloshinskii-Moriya interaction can lead to the formation of skyrmions in crystal lattices with a broken inversion symmetry, as it is the case at interfaces of artificial heterostructures. Néel-type skyrmions were proposed to form in bilayers of ferromagnetic $SrRuO_3$ and paramagnetic $SrIrO_3$ with strong spin-orbit coupling as indicated by the observation of a topological hall effect [1].
Heterostructures of $SrRuO_3$ and $SrIrO_3$ on $SrTiO_3$ substrates show a rather bad structural compatibility due to the large lattice mismatch of about 1.1 % between $SrIrO_3$ and the substrate. To address this, we reduced the lattice constant of the iridate by doping it with calcium. Superlattices composed of $[SrRuO_3]_5/[Ca_xSr_{1-x}IrO_3]_2$ with various levels of doping were grown on STO (001) substrates by the means of metal-organic aerosol deposition. The structural properties of the samples were studied by x-ray diffraction, reciprocal space mapping and TEM imaging. Hall measurements were carried out to search for topological contributions as an indication for the formation of skyrmions and compared with the results of [1,2].

[1] J. Matsuno *et al.*, Science Adv. **2** (2016) e1600304.
[2] S. Esser *et al.*, Phys. Rev. B **103** (2021) 214430.

MA 23.10 Tue 17:00 P1

Magnon propagation across Quantum Hall Skyrmion crystals — •Nilotpal Chakraborty[1], Roderich Moessner[1], and Benoit Doucot[1,2] — [1]Max Planck Institute for Physics of Complex Systems, Dresden — [2]LPTHE, CNRS and Sorbonne Universite,

Skyrmion crystals have a rich collective mode spectrum and are hypothesized to appear in quantum Hall ferromagnets in the lowest Landau level at small dopings away from one filled level. We develop a model of a ferromagnet-skyrmion crystal-ferromagnet junction, relevant to recent experiments in monolayer graphene, to study the influence of collective modes of skyrmion crystals on the propagation of a ferromagnetic magnon. We show, using an appropriate set of generalized theta functions, how to smoothly interpolate between regions of zero (the ferromagnetic ends) and spatially modulating finite topological charge density (the sandwiched skyrmion crystal). The collective mode equations for such a configuration, from a suitably defined energy functional, map onto the Bogoliubov-De Gennes equation. Using this mapping, along with a slice-wise recursive transfer matrix approach, we calculate the transmission amplitudes of an incoming ferromagnetic magnon. We also show how changing the collective mode spectrum of the skyrmion crystal, by varying the strength of the topological charge density terms in the functional, affects magnon transmission. Our results present unique signatures of Skyrmion crystals due to their characteristic collective mode spectrum, and can be used as evidence for their presence in graphene and possibly in twisted bilayer graphene.

MA 23.11 Tue 17:00 P1

Magnetization dynamics of skyrmions in thin film and bulk materials — •Philipp Schwenke[1], Ephraim Spindler[1], Raphael Gruber[2], Vitaliy Vasyuchka[1], Aisha Aqeel[3], Mathias Kläui[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55122 Mainz, Germany — [3]Physik-Department, Technische Universität München, 85748 Garching, Germany

Magnetic skyrmions are topologically protected chiral spin textures which hold a rich variety of phenomena and that can be stabilized in both bulk materials and thin films. In order to establish effiecient means to control skyrmions it is important to understand the magnetization dynamics of these magnetic textures. Therefore, we study the magnetization dynamics of a CoFeB thin film exhibiting μm sized quasi 2D skyrmions [1] and compare these to the dynamics observed in a bulk Cu_2OSeO_3 crystal exhibiting a skyrmion lattice phase [2] by means of broadband ferromagnetic resonance measurements at varying temperatures. Additionally, we investigate the dynamics of μm sized quasi 2D skyrmions in CoFeB-based thin film heterostructures in a Kerr-microscope while applying out-of plane rf fields. We observe a perturbation of the skyrmion lattice due to finite size oscillations which might provide a pathway for the manipulation of skyrmion lattices.

[1] J. Zázvorka *et. al*, Adv. Funct. Mater. **30**, 2004037 (2020)
[2] A. Aqeel *et. al*, Phys. Rev. B **103**, L100410 (2021)

MA 23.12 Tue 17:00 P1

Static and dynamical properties of magnetic (bi-)skyrmions in the absence of Dzyaloshinskii-Moriya interaction — •David Eilmsteiner[1], Levan Chotorlishvili[2], Xi-guang Wang[3], Paweł Buczek[4], and Arthur Ernst[1] — [1]Johannes Kepler University Linz, Linz, Austria — [2]Rzeszów University of Technology, Rzeszów, Poland — [3]Central South University, Changsha , China — [4]Hamburg University of Applied Sciences, Hamburg, Germany

The interest in topologically non-trivial states in magnetic materials, for instance magnetic skyrmions, arises not only from the fascinating connection between the mathematical concept of topology and phenomena observable in the lab, but also from possible future applications of those configurations in technology. The main obstacle towards a future technological applicability is the limited range of materials in which skyrmions intrinsically occur – for instance, Dzyaloshinskii-Moriya interaction is usually required. However, a sophisticated design of multi-layer systems can help to circumvent this constraint. My poster will discuss two such set-ups. The one demonstrates how a circular nanodot in combination with a switching magnetic field can help to nucleate a magnetic skyrmion. The other studies the motion of a bi-skyrmion bound to a vortex-domain wall. In the latter case, we not only found the, for technological application highly favorable, disappearance of the skyrmion Hall effect, we also observed a chirality dependence of the propagation velocity.

MA 23.13 Tue 17:00 P1

muSR on single crystals of GaV4S8 — •Elaheh Sadrollahi[1,2], Andre Borchers[2], Jochen Litterst[2,3], István Kézsmárki[4], Sandor Bordacs[5], Vladimir Tsurkan[4], and Alois Loidl[4] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Institut für Physik der kondensierten Materie, Technische Universität Braunschweig, 38110 Braunschweig, Germany — [3]Centro Brasileiro de Pesquisas Físicas, 22290-180, Rio de Janeiro, RJ, Brazil — [4]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [5]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary

The lacunar thio-spinel GaV4S8 possesses a complex magnetic phase diagram with several magnetic phases in zero and applied field, in part with supposed cycloidal, ferromagnetic, and/or short-range cycloidal spin structures, eventually even including skyrmion structures in the ferromagnetic phase [1,2]. We have performed muon spin rotation and relaxation (muSR) experiments on oriented single crystals. In a zero magnetic field, the spontaneous rotation signals allow us to distinguish between the cycloidal (ca. 8-13 K) and the low temperature 'ferromagnetic' phase, yet with a smooth continuous transition extending over several degrees, which is interpreted with a spin-reorientation. The observed changes at low temperatures and in the applied field indicate that this phase has no simple ferromagnetic character. We will discuss the observed field distribution patterns under various applied fields.[1] I. Kezsmarki et al., Nature Mater. 14, 1116 (2015).[2] S.Widmann et al., unpubl., arXiv 1606.04511 (2016).

MA 23.14 Tue 17:00 P1

Bloch points in helimagnetic nanostrips — •Martin Lang[1,2], Marijan Beg[1,3], Ondrej Hovorka[1], and Hans Fangohr[1,2,4] — [1]University of Southampton, Southampton, United Kingdom — [2]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [3]Imperial College London, London, United Kingdom — [4]Center for Free-Electron Laser Science, Hamburg, Germany

Complex magnetic materials hosting topologically non-trivial particle-like objects such as skyrmions are intensely researched. One important class of materials are helimagnetic materials with Dzyaloshinskii-Moriya interaction. Recently, it was demonstrated that nanodisks consisting of two layers with opposite chirality can host a single stable Bloch point (BP) of two different types [1]. The BP represents an interesting topological excitation in a helimagnetic system, which expands the set of well-known magnetic states such as domain walls, vortices, and skyrmions.

In this work [2], we use micromagnetic simulations [3] to show that FeGe nanostrips consisting of two layers with opposite chirality can host multiple coexisting BPs. We demonstrate that the two different BP types can be geometrically arranged in any arbitrary order and these magnetization configurations are meta-stable. We can determine an optimal spacing between BPs within a line of BPs allowing us to predict strip geometries suitable for an arbitrary number of BPs.

[1] M. Beg et al., Scientific Reports, **9**, p. 7959 (2019). [2] M. Lang et al. arXiv:2203.13689 (2022). [3] M. Beg, M. Lang and H. Fangohr, IEEE Transactions on Magnetics, **58**, p. 7300205 (2022).

MA 23.15 Tue 17:00 P1

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

Research in 3D nanomagnetism, driven by advanced nanofabrication methods [1] and novel experimental 3D magnetization visualization methods [2], has revealed new nanostructures and physics beyond those in 1D and 2D. Magnetic Hopfions are topological magnetic textures that can be considered as closed loops of twisted Skyrmion strings [3]. The number of twists and knots of the Hopfion is characterized by the Hopf index. Both Skyrmions and Hopfions require the interplay of competing interactions to stabilize them. In contrast to Skyrmions, which can be stabilized, for example, by the competition of inversion symmetry-breaking Dzyaloshinskii-Moriya interactions and standard exchange interactions, Hopfions require competing exchange interactions beyond second-order derivatives [3,4]. We consider frustrated magnets that obey the interplay of such competing exchange interactions and want to investigate the physics of three-dimensional topological structures.

[1] P. Fischer et al., APL Mater. 8, 010701 (2020).
[2] C. Donnelly et al., Nature 547, 328 (2017).
[3] P. Sutcliffe, Phys. Rev. Lett. 118, 247203 (2017).
[4] F. N. Rybakov et al., APL Mater. 10, 111113 (2022).

MA 23.16 Tue 17:00 P1

Suppression of magnetic fluctuations lead to a better reversibility in low-field entropy changes near triple point — •Tapas Samanta[1], Chris Taake[1], and Luana Caron[1,2] — [1]Faculty of Physics, Bielefeld University, PO Box 100131, D-33501 Bielefeld, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin 12489, Germany

We report the detailed study of the phase transitions in $MnNi_{1-x}Co_xGe_{0.97}Al_{0.03}$ (x=0.20, 0.25 0.30, 0.35, 0.37, 0.40 and 0.45) compounds. In the parent Al-free compound, the structural and magnetic phase transitions are decoupled. Small amounts of Al substitution for Ge can lower the structural phase transition temperature, resulting in a coupled first-order magnetostructural transition (MST) near room temperature for all reported compositions. An antiferromagnetic-type (AFM) to paramagnetic (PM) MST has been observed for lower Co concentrations. At x=0.37 the phase transition transforms to a ferromagnetic-type (FM) to PM MST after exhibiting a triple point (where AFM, FM and PM phase transitions coincide) in the close vicinity of x=0.36. Interestingly, a relatively large reversible low-field entropy change (ΔS=-6.9 J/kg K for ΔH=2 T) has been observed near the triple point for x=0.37, which is rather rare in this class of materials due to the large associated thermal hysteresis. The observed reversible ΔS reaches values of -17.2 and -24.5 J/kg K for ΔH=5 and 7 T, respectively, for x=0.30. Our observations further reveal that a sudden decrease of magnetic fluctuation results in larger reversible entropy change near triple point.

MA 23.17 Tue 17:00 P1

Probing the nature of first-order magnetostructural transitions as responsible for magnetocaloric effects: A case study for In-based Heusler alloys — •Chris Taake[1], Tapas Samanta[1], and Luana Caron[1,2] — [1]Faculty of Physics, Bielefeld University, PO Box 100131, D-33501 Bielefeld, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin 12489, Germany

The subtle nature of magnetostructural transitions (MST) and associated magnetocaloric effects (MCE) in B-substituted In-based Heusler alloys $Ni_{50}Mn_{34.8}In_{15.2-x}B_x$ (x=1, 2 and 3) have been studied. Boron substitution acts as a positive chemical pressure and shifts the martensitic phase transition temperature (T_M) towards higher temperature with increasing B concentration. Magnetic field sensitivity of T_M as well as thermal hysteresis decrease with increasing B substitution. Because of the compensation effect between the loss of field sensitivity and decreased thermal hysteresis, a similar reversible MCE can be expected for all studied compositions. However, a much better reversible isothermal entropy change (ΔS) has been observed for x=1, which reaches a value of +20.8 J/kg K for ΔH=5 T. The observed behavior clearly indicates that the nature of the MST responsible for the MCE is changing with composition. To understand the nature of the MST in depth, the behavior of the local magnetic field exponent, n ($\Delta S \propto H^n$), has been examined for all the compositions. Interestingly, a much larger n^{max} (=10.35, where n >2 is the indication of a first-order phase transition) has been detected for x=1 when compared to other compositions which are less field sensitive (n^{max}=3.66, x=3).

MA 23.18 Tue 17:00 P1

Magnetocaloric materials for the liquefaction of hydrogen — •Tino Gottschall[1], Eduard Bykov[1,2], Marc Strassheim[1,2], Timo Niehoff[1,2], Catalina Salazar-Mejia[1], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU 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 by adiabatic demagnetization of magnetic salts. Recently, low temperatures have once again become the focus of attention as an area of application for magnetocaloric cooling namely for hydrogen liquefaction. In this work, we would like to discuss our current progress for the creation of a materials library for cryogenic applications. The basis for this is our characterization infrastructure for materials research at the Dresden High Magnetic Field Laboratory in static and pulsed fields. With this, we aim to understand these materials better to further optimize their magnetic cooling performance near the boiling temperature of hydrogen.

MA 23.19 Tue 17:00 P1

Direct measurements of the adiabatic temperature change in heavy rare-earth $R\mathrm{Co}_2$ compounds in high magnetic fields — •E. Bykov[1,2], T. Gottschall[1], K. Skokov[3], A. Karpenkov[3], W. Liu[3], F. Scheibel[3], O. Gutfleisch[3], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Technische Universität Darmstadt, Darmstadt, Germany

Rare-earth elements and their intermetallic compounds are interesting candidate materials for magnetic cooling at and below room temperature. Although the group of heavy rare-earth Laves phases RM_2 (R is a rare earth, M a transition metal) is one of the most intensively investigated classes of magnetocaloric materials, data on directly determined adiabatic temperature changes are scarce. Continuing our work with ferromagnetic $R\mathrm{Ni}_2$ and $R\mathrm{Al}_2$ compounds, we are now focussed on ferrimagnetic $R\mathrm{Co}_2$. Some of them show complex magnetic behavior, such as metamagnetism at T_C, or an additional spin-reorientation transition and reduction of the Co magnetic moment below this temperature. In this work, we present a comprehensive analysis of the magnetocaloric effect in polycrystalline $R\mathrm{Co}_2$ with R = Er, Ho, Dy, and Tb in high magnetic fields up to 20 T.

MA 23.20 Tue 17:00 P1

Single Molecule Magnets based on dimetallofullerenes — •Matheus Barbosa, Wei Yang, Fupin Liu, and Alexey Popov — Leibniz Institute for Solid State and Materials Research - Dresden, Germany

Dimetallofullerenes are compounds with metal-metal bonds encapsulated in fullerene cages, recognized as good Single Molecule Magnets (SMMs). In the last years, molecules based on Terbium (Tb) and Dysprosium (Dy) have been demonstrating high potential applicability owing to the strong ferromagnetic coupling of 4f-electrons and trapped valence electron of the bond between them. Their static and dynamic properties are under investigation and have showed high blocking temperatures of magnetization, giant coercive fields and complexes relaxation processes. Dy-Dy dimer inside the fullerene cage C_{80} ($Dy_2@C_{80}$) shows different magnetic behavior depending on the chosen stabilizing chemical groups. In comparation, for $Dy_2@C_{80}(CF_3)$ the susceptibility χ_m per temperature (ZFC-FC curves) is observed to be double-peak below 21 K, with the shape dependent of the temperature and field sweep rates, in contrast to $Dy_2@C_{80}(CH_2C_6H_5)$. The estimated energy barrier (613 K for $\{Dy_2\}-CF_3$ and 615 K for $\{Dy_2\}-CH_2C_6H_5$) and the ferromagnetic coupling constant have the similar values. However, at low temperature in zero magnetic field (QTM regime) the relaxation rate is c.a. 10 times faster for $\{Dy_2\}-CF_3$ than for the $\{Dy_2\}-CH_2C_6H_5$. Dilution studies demonstrated that this difference does not depend on the intermolecular interactions and should be ascribed to a different influence of the exohedral group.

MA 23.21 Tue 17:00 P1

Study of magneto-electric (M-E) coupling effect in spin triangle based metal (III) carboxylate [M3O(O2CPh)6(py)3] ClO4.py (M= Fe, Ga) molecular magnet. — •Balwant Singh Chauhan[1], Ratnamala Chatterjee[1], AK Boudalis[2], and P Turek[2] — [1]Department of Physics, IIT Delhi, Hauz Khas, New Delhi 110016, India — [2]Institut de Chimie de Strasbourg (UMR 7177, CNRS-Unistra), Université de Strasbourg, 4 rue Blaise Pascal, CS 90032, Strasbourg, 67081, France

Materials with magneto-electric coupling effect having coupled magnetic and electric properties have potential applications in energy efficient data storage and other multifunctional device technology. In recent literature organic molecules like molecular magnets/molecular ferroelectric materials are being explored for their possible novel magneto-electric characteristics. In this context, a work by French group [1] on Fe spin triangle based metal carboxylates [F3O(O2CPh)6(py)3]ClO4.py have attracted a lot of attraction. In this work, we would clearly demonstrate a correlation between dielectric and magnetic properties of the [F3O(O2CPh)6(py)3]ClO4.py complex. The highlight of the work is the observation of direct ME coupling coefficient in this molecular magnet complex. A comparison of the same with nonmagnetic Ga(III) complex will be discussed too. References: [1] A. K. Boudalis, J. Robert and P. Turek, Chemistry - A European Journal, 24 (2018) 56

MA 23.22 Tue 17:00 P1

Chiral induced spin selectivity effect at hybrid molecule metal interfaces. — •Ashish Moharana[1], Shuanglong Wang[2], Hao Wu[2], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1], Tomasz Marszalek[2], Qiu Zijie[2,3], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Max Planck Institute for Polymer Research, Ackermannweg 10, 55128, Mainz, Germany — [3]Shenzhen Institute of Aggregate Science and Technology, School of Science and Engineering, The Chinese University of Hong Kong, 2001 Longxiang Boulevard, Longgang District, Shenzhen City, Guangdong, 518172, China

The observation of spin-dependent transmission of electrons through chiral molecules has led to the discovery of chiral-induced spin selectivity. The high efficiency of the spin filtering effect in chiral molecules has recently gained significant interest due to the high potential for novel hybrid molecule magnetic spintronics applications. In our work, we explore spintronic phenomena at hybrid chiral molecule magnetic interfaces to elucidate the underlying mechanisms of the chiral-induced spin selectivity effect. For this, we investigate the spin-to-charge conversion efficiency in chiral molecule/ metallic thin film heterostructures. Quantifying the impact of the adsorption as a function of the structure of the chiral molecules will reveal the role of the structural design in the spin filtering effect paving the path towards three dimensional engineering of hybrid interfaces.

MA 23.23 Tue 17:00 P1

Chiral induced spin selectivity effect at hybrid molecule metal interfaces. — •Ashish Moharana[1], Shuanglong Wang[2], Hao Wu[2], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1], Tomasz Marszalek[2], Qiu Zijie[2,3], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Max Planck Institute for Polymer Research, Ackermannweg 10, 55128, Mainz, Germany — [3]Shenzhen Institute of Aggregate Science and Technology, School of Science and Engineering, The Chinese University of Hong Kong, 2001 Longxiang Boulevard, Longgang District, Shenzhen City, Guangdong, 518172, China

The observation of spin-dependent transmission of electrons through chiral molecules has led to the discovery of chiral-induced spin selectivity. The high efficiency of the spin filtering effect in chiral molecules has recently gained significant interest due to the high potential for novel hybrid molecule magnetic spintronics applications. In our work, we explore spintronic phenomena at hybrid chiral molecule magnetic

interfaces to elucidate the underlying mechanisms of the chiral-induced spin selectivity effect. For this, we investigate the spin-to-charge conversion efficiency in chiral molecule/metallic thin film heterostructures. Quantifying the impact of the adsorption as a function of the structure of the chiral molecules will reveal the role of the structural design in the spin filtering effect paving the path towards three dimensional engineering of hybrid interfaces.

MA 23.24 Tue 17:00 P1

Density-functional studies of Cu-based metallacrowns on metal surfaces — •Abolfazl Tavakoli[1], Benjamin Stadtmüller[1], and Hans Christian Schneider[1,2] — [1]Department of Physics and OPTIMAS Research Center, TU Kaiserslautern — [2]Institute of Physics, Johannes Gutenberg University Mainz

Metallacrowns are a promising material system for single-molecule magnets as they exhibit favorable chemical and structural features. Here, we present a first-principles study of the electronic and magnetic properties of Cu4-Cu metallacrown complexes adsorbed on an Au (111) surface. We benchmark our calculations on the drosophila system CuPc and discuss the changes of the ligand structure and DOS around the metal centers. As an outlook, preliminary results on the Fe4-Cu metallacrown will also be presented.

MA 23.25 Tue 17:00 P1

Origin of Ferromagnetism in the Copper(II) Triangle $\mathbf{NMe_4[Cu_3(\mu_3\text{-}F)(TFA)_6(Py)_3]}$ — •Kevin Ackermann[1,2], Changhyun Koo[1], Ahmed Elghandour[1], Rüdiger Klingeler[1], and Maurits W. Haverkort[2] — [1]1Kirchhoff Institute for Physics, Heidelberg, Germany — [2]for Theoretical Physics, Heidelberg, Germany

The new copper(II) triangle $NMe_4[Cu_3(\mu_3\text{-}F)(TFA)_6(Py)_3]$ [1] was studied using magnetic susceptibility and high-field electron paramagnetic resonance (HF-EPR) experiments, as well as numerically by ab-initio methods. The magnetization and susceptibility data reveal dominant ferromagnetic spin-spin exchange as well as the importance of anisotropy in the system. An Anderson Impurity Model based on LDA-DFT calculations elucidates that the ferromagnetic interactions originate from super-exchange via the central fluorine. For the super-exchange interaction, not only the fluorine's $2p$ shell but also the $2s$ shell needs to be considered. In the HF-EPR date a substantial curvature of the resonance branches is observed and explained within the model by mixing between exited $S_z \approx 1/2$ and $S_z \approx -1/2$ states. The model also suggests that the spins are not parallel to each other in the ferromagnetic ground state but rather arranged in a chiral manner which is given by the molecular structure.

[1] A. Vassiliev *et al.*, unpublished.

MA 23.26 Tue 17:00 P1

Magnetization of magnetotactic bacteria: influence of additional nitrate during incubation — •Nicole Sander, Imke Wellesen, and Mathias Getzlaff — Institute of Applied Physics, Heinrich-Heine-Universität Düsseldorf

Magnetotactic bacteria (MTB) have the ability to orient and migrate along a magnetic field. The orientation of those bacteria is based on intracellular magnetic structures called magnetosomes, which are formed from magnetite surrounded by a lipid-biolayer. These magnetic properties of MTB are currently of interest for magnetic hyperthermia as an application for cancer therapy.

Here we report on new findings how additional nitrate during incubation of MTB can prolong cell formation and increase magnetization. With additional nitrate we found, that the storage in an incubator can be extended and magnetosome concentration per bacteria was increased due to higher cell mass. A feeding of MTB after five days of incubation maximized the messured optical density being a measure for the number of bacteria respectivly a feeding on the seventh day of incubation maximized magnetization. The data was obtained twenty-four hours after adding nitrate and further incubation. Considering a longer incubation period the data shows, that incubating up to fourty-eight hours after feeding bacteria with nitrate apopotsis can be delayed. These findings display an advantage for magnetic hyperthermia because of higher cell mass and magnetosome concentration per cell the specific absorption rate (SAR) will be enlarged. Otherwise for same SAR a smaller concentration of bacteria is needed.

MA 23.27 Tue 17:00 P1

The influence of storage on magnetotactic bacteria — •Imke Wellesen, Nicole Sander, and Mathias Getzlaff — Heinrich-Heine-Universität, Düsseldorf

Magnetic nanoparticles offer many new possibilities in medical applications e.g. in hyperthermia for cancer therapy. However, their production is largely challenging since it is often very complicated and costly. Therefore, the focus of research has been drawn to special organisms: Magnetotactic bacteria (MTB) naturally synthesize magnetic nanoparticles to orient themselves along the earth's magnetic field. In the future they could be used as nanoparticle producers. A problem is the resulting dependence of the applications on the life cycles of the bacteria. Therefore, optimal storage conditions must be evaluated so that the nanoparticles may still be used effectively at all times.

In this work we investigated the influence of storage at room and low temperatures on the bacteria and nanoparticles. The bacterial growth was examined via the optical density. The progression of the optical density and magnetisation of the organisms was observed over a period of 19 days. The results showed the positive effect of low temperatures on the bacteria. Storage at room temperature resulted in exponentially decreasing optical density and the destruction of the chain structure of the nanoparticles. Optical density and magnetisation of the bacteria at low temperatures on the other hand remained constant. Thus, the experiments showed that storage of magnetotactic bacteria should be realised at lower temperatures.

MA 23.28 Tue 17:00 P1

Biomarker detection using Frequency Mixing Magnetic Detection Technique — •Faranak Eivazi and Hans-Joachim Krause — Institute of Biological Information Processing (IBI-3), Forschungszentrum Jülich

Superparamagnetic nanoparticles (SPNs) with non-hysteretic magnetization curves have significant potential for biomarker detection. The aim of our study is to probe the binding states of targets to SPNs using the frequency mixing magnetic detection technique (FMMD) [1]. As the SPNs bind to the target, the change in the hydrodynamic radius of the system leads to a longer Brownian relaxation time. The FMMD exposes SPNs bound to their targets to 2 alternating magnetic fields. The low-frequency field f_2 with high amplitude drives the SPNs to saturation, and a high-frequency field f_1 with low amplitude is used to probe the nonlinear magnetization. The response of the particles induces a voltage in the detection coil. The demodulated frequency mixing harmonics $f_1 + nf_2$ are characteristic of particle properties. The hydrodynamic radius of SPNs can be determined by observing a phase shift toward lower frequencies caused by the longer Brownian relaxation of the particles. This method can be used to determine the quantity and size of the target in the sample. [1] S. Achtsnicht, et al., PLoS ONE, 14(7), 2019.

MA 23.29 Tue 17:00 P1

Methods of electron transport in the theory of spin stiffness — •Ilja Turek[1], Josef Kudrnovsky[2], and Vaclav Drchal[2] — [1]Institute of Physics of Materials, Czech Acad. Sci., Brno, Czech Rep. — [2]Institute of Physics, Czech Acad. Sci., Prague, Czech Rep.

We present an ab initio theory of the spin-wave stiffness for itinerant ferromagnets [1] with pair exchange interactions derived from the magnetic force theorem [2]. The resulting formula involves one-particle propagators and effective velocity operators appearing in a recent theory of electron transport [3]. Application of this approach to clean crystals allows one to overcome the problem of ill-converging lattice summations, as documented by results for pure metals Fe, Co, and Ni. Application to random alloys within the coherent potential approximation, illustrated by results for fcc Ni-Fe and bcc Fe-Al systems, enables one to include the disorder-induced vertex corrections, often neglected in evaluation of the exchange interactions.

[1] I. Turek et al., Phys. Rev. B 101 (2020) 134410. [2] A. I. Liechtenstein et al., J. Magn. Magn. Mater. 67 (1987) 65. [3] I. Turek et al., Phys. Rev. B 65 (2002) 125101.

MA 23.30 Tue 17:00 P1

Abelian spin-Berry curvature of the Haldane model and non-Abelian generalisation — •Nicolas Lenzing, Simon Michel, and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, University of Hamburg

The feedback of the geometrical Berry phase, accumulated in an electron system, on the slow dynamics of classical degrees of freedom is governed by the Berry curvature. Here, we study local magnetic moments, modelled as classical spins, which are locally exchange coupled to the (spinful) Haldane model. In the emergent equations of motion for the slow classical-spin dynamics there is a an additional anomalous geometrical spin torque, which originates from the corresponding spin-Berry curvature. Due to the explicitly broken time-reversal symmetry, this is nonzero but usually small in a condensed-matter system. We develop the general theory and compute the spin-Berry curvature, mainly in the limit of weak exchange coupling, in various parameter regimes, particularly close to a topological phase transition. The spatial structure of the spin-Berry curvature tensor, its symmetry properties and the distance dependence of its nonlocal elements are discussed. The investigation has been done in the strict adiabatic limit, where one considers the groundstate only, resulting in an Abelian spin-Berry curvature. It is possible to generalise the formalism for a relaxed adiabatic constraint that takes into account a low-energy subspace. This type of subspace arises, for example, in the case of a degenerate groundstate. The spin-Berry curvature corresponding to the subspace is non-Abelian and does not necessarily vanish for time-reversal symmetric systems.

MA 23.31 Tue 17:00 P1

Nonlocal correlation effects due to virtual spin-flip processes in itinerant electron ferromagnets — •Sebastian Paischer[1], Mikhail Katsnelson[2], Giovanni Vignale[3], Arthur Ernst[1], and Pawel Buczek[4] — [1]Johannes Kepler University, Linz, Austria — [2]Radboud University, Nijmegen, Netherlands — [3]National University of Singapore, Singapore — [4]Hamburg University of Applied Sciences, Hamburg, Germany

An important type of the many-body effects in itinerant-electron magnets originates from the interaction of electrons with bosonic spin-flip excitations, both coherent (magnons) and incoherent (Stoner particle-hole excitations). While there has been a steady progress in understanding the properties of spin-flip excitations at a model level only little is known about microscopic details of their interactions with the electronic degrees of freedom in specific materials. Over the last few years we developed a first-principles method to account for the electron-magnon interaction in complex solids. While the method is based upon many body perturbation theory, we approximate the complex quantities from perturbation theory with quantities from time dependent density functional theory. This drastically reduces the numerical burden of the calculations and allows to consider complex materials like half-metallic ferromagnets. In this poster session some details of the theory and selected results will be presented.

MA 23.32 Tue 17:00 P1

Exploration of 2D magnetic matierials using parallelized HSE functionals in FLEUR — •Sabastian Granberg Cauchi[1,2], Daniel Wortmann[1], Gregor Michalicek[1], and Stefan Blügel[1,2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany — [2]RWTH Aachen University, Germany

Density functional theory has become a standard of electronic structure calculations, often implemented in the LDA/GGA approximations. Increased accuracy can be achieved in many systems using computationally expensive hybrid functionals, e.g. PBE0 and HSE, which factor in the exact exchange energy. An implementation of hybrid functionals in the all-electron full-potential linearized augemented-plane-wave code FLEUR [1,2,3] has been realized and applied to many materials, e.g. perovskites and rare-earth compounds, in the past. Recently, high-performance techniques have been employed to achieve extreme parallelization scaling of the PBE0 implementation for optimized supercomputer use [4]. In this study, these techniques are extended to the HSE06 functional and applied to 2D magnetic materials.

We acknowledge financial support by MaX CoE funded by the EU through H2020-INFRAEDI-2018 (project: GA 824143).

[1] M. Betzinger et al., Phys. Rev. B 81, 195117 (2010).
[2] M. Schlipf, Phys. Rev. B 84, 125142 (2011).
[3] FLEUR official website, flapw.de
[4] M. Redies, Front. Mater. 9, doi:10.3389/fmats.2022.851458 (2022).

MA 23.33 Tue 17:00 P1

Magnon excitations in two-dimensional doped Antiferromagnets — •Pit Bermes — Department of Physics and Arnold Sommerfeld Center for Theoretical Physics (ASC), Ludwig-Maximilians-Universität München, Theresienstr. 37, München D-80333, Germany — Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 München, Germany

When a mobile hole is doped into an antiferromagnet, its movement will distort the surrounding magnetic order and yield a magnetic polaron. The resulting complex interplay of spin and charge degrees of freedom gives rise to very rich physics and is widely believed to be at the heart of high-temperature superconductivity in cuprates. Although the parton theory has been successful in describing many properties of these magnetic polarons, it is still unclear how these couple to the collective magnon excitations. In this paper, we derive this effective coupling between the polaron and magnons and their influences on the polaron's properties. We therefore start from a single hole doped into an AFM described in the aforementioned polaron model by a 'geometric string' and will then introduce magnon excitations through a generalized $1/S$ expansion to arrive at an effective Hamiltonian. After making a Born-Oppenheimer-type approximation, this system will be solved using the self-consistent Born approximation to extract the renormalized polaron properties, like its dispersion relation and the single-particle spectrum.

MA 23.34 Tue 17:00 P1

Self-assembly as a tool to study microscale curvature and strain-dependent magnetic properties — •Balram Singh[1], Jorge. A. Otálora[2], Tong H. Kang[1], Ivan Soldatov[1], Dmitriy D. Karnaushenko[3], Christian Becker[3], Rudolf Schäfer[1], Daniil Karnaushenko[3], Volker Neu[1], and Oliver G. Schmidt[3] — [1]Institute for Integrative Nanosciences, Leibniz IFW Dresden, 01069 Dresden, Germany. — [2]Departamento de Física, Universidad Católica del Norte, Avenida Angamos 0610, Casilla 1280 Antofagasta, Chile — [3]Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, 09126 Chemnitz, Germany

The extension of 2D ferromagnetic structures into 3D curved geometry enables tuning its magnetic properties such as magnetic anisotropy. Tuning the anisotropy with strain and curvature has become a promising ingredient in modern magnetoelectronic devices, however, has been limited to extended thin films and to only moderate bending. By applying a self-assembly rolling technique using a polymeric platform, we provide a template that allows homogeneous and controlled bending of a functional layer adhered to it, irrespective of its shape and size. This is an intriguing possibility to tailor the sign and magnitude of the surface strain of integrated, micron-sized devices. In this article, the impact of strain and curvature on the magnetic ground state and anisotropy is quantified for thin-film Permalloy micro-scale structures, fabricated on the surface of the tubular architectures, using solely electrical measurements.

MA 23.35 Tue 17:00 P1

Switchable magnetic probe for scanning probe microscopy — •Rachappa Ravishankar, Aniruddha Sathyadharma Prasad, Stefan Baunack, Thomas Mühl, Volker Neu, Rudolf Schäfer, and Bernd Büchner — Leibniz Institute for Solid State and Materials Research (IFW) Dresden

Magnetic force microscopy (MFM) has been demonstrated as a valuable technique for the characterization of magnetic nanomaterials. Conventional MFM is a two-pass method, in which the topography of the surface is first obtained by probing the strong Van der Waals and other short-range interactions between probe and sample. During the second scan, the probe is lifted away from the sample, and it experiences long-range magnetic and electrostatic interactions.

A typical approach to disentangle magnetic from non-magnetic signals is by switching the magnetization of the tip in a global external field by means of physically removing the tip from the MFM setup. In the course of our work, we aim at developing an on-chip solution for switching the magnetization of a magnetic probe. We accomplish this by a local Oersted field from a current carrying planar coil, lithographically patterned on either the tip or sample.

This poster highlights switching tip magnetization by a homogeneous field source from a macroscale electromagnetic coil versus an inhomogeneous field from lithographically patterned micro coils on the sample. We showcase this for: (i) commercial MFM probes, and (ii) commercial MFM probes tailored by focused ion beam milling.

MA 23.36 Tue 17:00 P1

Imaging magnetization dynamics of non-bubble domains in ferromagnetic multilayer systems for quantification of Dzyaloshinskii-Moriya interaction (DMI) — •Arne Vereijken[1], Sapida Akhundzada[1], Florian Ott[1], Maxwell Li[2], Tim Mewes[3], Michael Vogel[1], Vincent Sokalski[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany — [2]Department of Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, USA — [3]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, USA

DMI promotes chiral coupling between spins [1], giving rise to robust, chiral spin textures, e.g., skyrmions with excellent properties for information storage and processing [2]. Recently it has been demonstrated that the DMI is measurable via imaging of magnetization dynamics of bubble domains, which possesses great potential in becoming an experimental standard method [3]. By enhancing this method with a self-segmentation for growth identification, more complex domain shapes may be accessible. We systematically studied the DMI in a perpendicularly magnetized ferromagnet/heavy metal system with different dendrimeric domain textures. [1] T. Moriya, New Mechanism of Anisotropic Superexchange Interaction, Phys. Rev. Lett. 4 (1960) [2] C. Back et al., The 2020 Skyrmionics Roadmap, J. Phys. D 53.36 (2020) [3] A. Magni et al., Key Points in the Determination of the Interfacial DMI from Asymmetric Bubble Domain Expansion, (2022)

MA 23.37 Tue 17:00 P1

Kerr microscopy for all-optical helicity-dependent magnetization switching (AOHDS) — •Lucas Vollroth[1], Marcel Kohlmann[1], Kristýna Hovořáková[2], Eva Schmoranzerová[2], Markus Münzenberg[1], and Jakob Walowski[1] — [1]Greifswald University, Greifswald, Germany — [2]Charles University, Prague, Czech Republic

The demand of data storage capabilities is growing rapidly since the invention of the computer. The development of big data in science and economy intensifies this evolution. To fulfill the demand of storage capabilities there is need of new data storage techniques. One of these new techniques is heat assisted magneto recording (HAMR) where the bit size is drastically decreased by high coercive fields of granular FePt.

Besides the heat assisted writing with a magnet, we are investigating the writing on HAMR media with all-optical helicity-dependent switching (AOHDS) as a novel data storage technology [1]. Wide field Kerr-microscopy is a well-suited method to explore and analyze the outcome of our AOHDS experiments.

We present a build from scratch and cost-efficient Kerr microscope for the observation of magnetic domains and writing with AOHDS on HAMR media simultaneously. It can also be used for the investigation of skyrmions and can be refined to investigate magnetization changed in a pump-probe experiment after the deposition of ultrashort laser pulses on magnetic thin films.

[1] John, R. et al. Magnetisation switching of FePt nanoparticle recording medium by femtosecond laser pulses. Sci Rep 7, 4114 (2017)

MA 23.38 Tue 17:00 P1

Nitrogen Vacancy Center in Diamond - Study of Correlated Electron Systems — •Sreehari Jayaram and Malik Lenger — 3rd Physics Institute, University of Stuttgart, Allmandring 13, Stuttgart, Germany

Investigation of emergent nanoscale magnetic properties of materials is a challenging field, which requires both, high sensitivity and spatial resolution. The scanning probe magnetometry based on the nitrogen-vacancy (NV) center in diamond is capable to fulfill these requirements and delivers complete vectorial magnetic field reconstructions. Due to optically detected magnetic resonance (ODMR), the NV center can operate as a quantum sensor from cryogenic temperatures up to room temperature with a frequency range from DC to GHz under high bias field conditions and UHV. In combination with atomic force microscopy, a sensor-sample distance of a few nanometers can be achieved with an NV-containing diamond AFM tip.

This has enabled investigations into the imaging of magnetic domains in single-layer CrBr3, the coexistence of AFM and FM domains in Moire twisted CrI3 trilayer, antiskyrmions in Heusler compounds, etc.

Thus, NV magnetometry opens the path to observe static and dynamic magnetic phenomena with nanoscale spatial resolution at a wide temperature range.

MA 23.39 Tue 17:00 P1

Improvement of Magnetic Force Microscopy measurements using magnetics tips grown by Focused Electron Beam Induced Deposition — •A.T. Escalante-Quiceno[1], V.V Fernández[2], A. Hierro-Rodríguez[2,3], J.I. Martín[2,3], C. Magén[1,4], and J.M De Teresa[1,4] — [1]Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza, 50009 Zaragoza, Spain — [2]Depto. Física, Universidad de Oviedo, 33007 Oviedo, Spain — [3]CINN (CSIC-Universidad de Oviedo), 33940 El Entrego, Spain — [4]Laboratorio de Microscopías Avanzadas (LMA), Universidad de Zaragoza, 50009 Zaragoza, Spain

We report the fabrication of magnetic tips for Magnetic Force Microscopy (MFM) using Focused Electron Beam Induced Deposition (FEBID). Due to their high aspect ratio and metallic content, these magnetic tips present a good magnetic behaviour, providing a number of advantages as lower non-magnetic tip-sample interaction, higher lateral resolution and higher coercivity than commercial magnetic tips when used for simultaneous topographical and magnetic measurements. A sharp tip apex with a diameter of 10 nm enables a high lateral resolution. Depending on the particular needs of the samples, the shape, length and diameter of the tip can be adjusted in a reproducible way. Because of its versatility, FEBID can produce magnetically hard tips customized with specific requirements. Ni80Fe20/NdCo5 bilayers with perpendicular magnetic anisotropy will be measured with FEBID-grown magnetic tips, where the resolution limit in MFM measurements will be tested.

MA 23.40 Tue 17:00 P1

Spatio-temporal Characterization of 3D Perovskites with Faraday Holography — •Julia Anthea Gessner, Jonathan Zerhoch, Shangpu Liu, and Felix Deschler — Physikalisch-Chemisches Institut, Im Neuenheimer Feld 229, Heidelberg, Germany

Hybrid metal halide perovskites have shown to be a promising class of semiconducting materials for a variety of applications ranging from LEDs, solar cells to spintronic devices. Compared to conventional materials, perovskites exhibit some advantageous features as a high quantum efficiency and tunability in the visible range, as well as a strong spin-orbit coupling for an efficient optical spin manipulation.

A preliminary step towards the integration of perovskites in spintronic devices is the time- and space-resolved optical study of their magnetic properties. In the present work, we study the spatio-temporal spin dynamics of Methylammonium Lead Tribromide (MAPbBr3) by the unique combination of two spectroscopic methods: time-resolved Faraday rotation spectroscopy and off-axis holographic imaging. The Faraday angle, which is a measure for the materials' magnetic moment, is imaged by an Ultrafast Transient Holographic Microscope (UTHC). The UTHC works as an all-optical lock-in amplifier with no upper limitations in the signal repetition rate.

By performing Faraday Holography at different temperatures and fluences, we are hence able to investigate the spatial evolution of optically spin-polarized excitons and identify the dominating spin relaxation mechanisms. This is essential for the optimization of the materials' properties and the future realization of spintronic systems.

MA 23.41 Tue 17:00 P1

Planar scanning probes - A new platform for nanoscale magnetometry with NV centers and nearfield microscopy — •Paul Weinbrenner[1], Stefan Ernst[2], Patricia Quellmalz[3], Christian Giese[3], and Friedemann Reinhard[1] — [1]Universität Rostock, Rostock, Germany — [2]ETH Zürich, Zürich, Switzerland — [3]Fraunhofer Institut für Angewandte Festkörper Forschung, Freiburg, Germany

We present the application of a new scanning probe technique to magnetometry with nitrogen-vacancy (NV) centers in diamond. Instead of using sharp tips we use flat mesas (shallow pillars) with a lateral size of 50 micrometers and height of up to 5 micrometers. Due to their geometry these so-called planar scanning probes offer a unique advantage for nanoscale magnetometry and novel optical near-field sensors.

Despite their large lateral size, they can still be scanned at a standoff distance of several nanometers. To achieve this alignment, we use tilt and distance control with optical far- and near-field measurements.

We fabricate planar diamond probes and use NV center quantum sensors for magnetic field measurements. The lateral size of the planar probes enables highly parallel scanning probe magnetometry. Additionally, the fabrication is less complex compared to conventional diamond tips.

With this new approach to scanning probe measurements, we propose the emergence of new material systems as sensors for nanoscale imaging. These next generation sensors include plasmonic nanostructures, defects in 2D materials, and encapsulated, single molecules.

MA 23.42 Tue 17:00 P1

Analysing the Domain Structure of a Thin Film and a GMR Stack with Magnetic Transmission Electron Microscopy — •Judith Bünte, Björn Büker, Daniela Ramermann, Inga Ennen, and Andreas Hütten — Universität Bielefeld, Dünne Schichten

und Physik der Nanostrukturen, Universitätsstr. 25, 33615 Bielefeld, Germany

The Transmission Electron Microscope (TEM) can be used to image magnetic domains in magnetic samples. Two prominent techniques for magnetic imaging are Differential Phase Contrast (DPC) and Lorentz Microscopy (LTEM). Both techniques base on the Lorentz force inside the magnetic domain of a specimen which deflects the transmitted electron beam depending on the orientation of the corresponding magnetic field. This deflected beam results in a different intensity distribution in the recorded image which can be analysed.

In this contribution both the DPC and the LTEM technique are used to image the magnetic landscape of two different model systems: One sample consists of pure cobalt, while the other sample is a nanostructured multilayer CoFe/Co/Ru sample. While the domains of the pure cobalt sample are unbound, the nanostructure inside the multilayer sample yields an interesting domain structure, which is constrained to the structure of the sample. Both samples are analysed quantitatively to draw conclusions regarding the characteristics of the samples through the measurements.

MA 23.43 Tue 17:00 P1

Application of high magnetic fields to micron-scale NMR spectroscopy with quantum sensors in diamond — •Rouven Maier, Jonas Meinel, Vadim Vorobyov, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart, Germany

Nuclear magnetic resonance (NMR) spectroscopy is widely used in fields ranging from chemical structure analysis to tissue imaging in clinical applications. The requirement of large sample volumes poses one of the major drawbacks of classical NMR measurements. Micron- and nano-scale NMR spectroscopy using quantum sensors, such as nitrogen-vacancy (NV) centers in diamond, has been a constant field of research over the past years. Recent developments of innovative detection schemes, such as the quantum-heterodyne (qdyne) protocol showed promising results by enabling resolutions independent of the inherent lifetime of the sensor spin. We present the experimental layout for the extension of quantum NMR sensing towards high magnetic fields, to enable chemical resolution at the micron-scale. This approach combines the frequency resolution necessary for chemical characterization with accurate spatial information. Signal sources could include ^{2}H, ^{13}C and ^{19}F from biomolecules and materials attached to the diamond surface.

MA 23.44 Tue 17:00 P1

Modulated spin-wave system for neuromorphic machine learning — •Jan Maskill, David Breitbach, Milan Ender, Burkard Hillebrands, and Philipp Pirro — Landesforschungszentrum OPTIMAS und Rheinland Pfälzische Technische Universität

In this work, a prototype physical reservoir based on spin-wave dynamics is developed and investigated numerically by micromagnetic simulations. The system under study is a nanometer-sized magnonic waveguide, on top of which a coplanar waveguide (CPW) antenna is placed for spin-wave excitation, as well as a localized region for spin current injection. The inputs of the reservoir are spin current pulses injected via the spin Hall effect, which modulates the amplitude of a carrier spin-wave created by the CPW. The carrier spin wave is reflected at the end of the waveguide, which allows for an interaction of the subsequent input signals. The resulting spin dynamics are shown to become highly nonlinear under the influence of the spin current. The output of the reservoir is its magnetic state as a function of time, which is calculated as part of numerical simulations. Based on an analysis using the kernel and generalization rank, it is shown that the reservoir exhibits a non linear input-output relation. In the kernel rank analysis, the nonlinearity of the reservoir is extracted with spatial resolution, uncovering regions of interest for possible output definitions. This work contributes to the realization of neuromorphic applications based on spin waves and helps to improve benchmarks for physical reservoirs.

MA 23.45 Tue 17:00 P1

Calculation of the temperature-dependent exchange stiffness from Domain Wall modelling — •Felix Schug[1,2], Nils Neugebauer[2,3], Michael Czerner[1,2], and Christian Heiliger[1,2] — [1]Institute for Theoretical Physics, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Center for Materials Research (LaMa), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [3]Institute of Experimental Physics I, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Understanding the different influences on the macroscopic magnetic properties of a material at finite temperatures is of great interest from a theoretical point of view. As macroscopic magnetic properties, such as anisotropies or the exchange stiffness, are related to the quantum nature of electrons and thus to the most fundamental level of solids, the atomic level, atomistic modelling of magnetic material may promote a more profound understanding of the microscopic processes. Performing the corresponding numerical simulations at various temperatures from 0 K to the Curie-temperature T_C, the temperature dependence of the associated macroscopic properties may be modelled. These modelled material parameters can be used to simulate magnetic properties in large-scale temperature-dependent micromagnetic simulations, leading to the so-called multiscale modelling approach. Here the approach of simulating Bloch walls of a finite cobalt stripe at different temperatures is demonstrated to extract the macroscopic crystalline anisotropy constant K_C and the exchange stiffness parameter A_{exc}.

MA 23.46 Tue 17:00 P1

Calculation of magnetic fields, forces and velocities by means of conductor trace segmentation using the example of the magnetic on-off ratchet. — •Torben Tappe, Inga Ennen, and Andreas Hütten — Bielefeld University, Bielefeld, Germany

For the evaluation of an optimal combination of ratchet geometry and particles, the calculation of the magnetic fields is essential, since in this way the acting forces on the particles and the resulting velocity of these can be determined prior to manufacturing. While the finite element method (FEM) is a standard tool for the calculation of magnetic fields of systems, in this work the trace segmentation is used for the modeling of the magnetic field occurring in the ratchet and is compared to the results of the FEM. Trace segmentation is based on the superposition principle, in which the magnetic field of a trace is approximated by many individual straight conductors whose magnetic fields are known. To evaluate the results of this method, various examples, ranging from just one trace to modeling an entire ratchet, were used and compared to Finite Element Method Magnetics (FEMM) calculations. These comparisons showed that the two methods, with a mean squared error of $2 \cdot 10^{-17}$ T to $3 \cdot 10^{-16}$ T, give the same results. This demonstrated that the trace segmentation is capable of reproducing the results of the standard tool FEM and therefore it is suitable for modeling a magnetic on-off ratchet.

MA 23.47 Tue 17:00 P1

Finite-size scaling for 5D Ising model with free boundary conditions — •Yulian Honchar[1,2,3], Bertrand Berche[1,4], Yurij Holovatch[1,3], and Ralph Kenna[1,2] — [1]$\mathbb{L}^4$ Collaboration & Doctoral College for the Statistical Physics of Complex Systems, Leipzig-Lorraine-Lviv-Coventry, Europe — [2]Centre for Fluid and Complex Systems, Coventry University, United Kingdom — [3]Institute for Condensed Matter Physics, National Acad. Sci. of Ukraine, Lviv, Ukraine — [4]Laboratoire de Physique et Chimie Théoriques, Université de Lorraine - CNRS, Nancy, Vandœuvre les Nancy, France

It is widely known that in systems with dimensionality higher than the upper critical, the scaling exponents assume their mean field values. However, in this case, the hyperscaling relation, which contains the dimensionality of space, is violated. In addition, mean-field exponents do not agree with the finite-size scaling. One of the theories that aimed to theoretically describe the behaviour of a finite-sized system is the Gaussian fixed point (so-called G-scaling) at which the interactions in the Landau-Ginsburg action are put to zero. Monte Carlo simulations of hypercubic lattices in the Ising model, where $d_{uc} = 4$, show that for periodic boundary conditions the exponents of the GFP do not correspond to the FSS. Another theory emerges with the introduction of a new exponent q into hyperscaling, which is equal to 1 for the dimensions $d \leq d_{uc}$, and $q = d/d_{uc}$ for higher dimensions. Q-scaling is confirmed for lattices with PBC. In this work, we investigated FSS on $d = 5$ lattices with free boundary conditions and showed that, unlike in systems with PBC, it is closer to G-scaling.

MA 23.48 Tue 17:00 P1

Equivalent Circuit for the Consideration of Frequency-Dependent Effects in Electronics Simulations of Induction Hobs — •Lennart Schwan[1,2], Michael Feige[1], Andreas Hütten[2], and Sonja Schöning[1] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Bielefeld University of Applied Sciences, Department of Engineering Sciences and Mathematics — [2]Thin Films & Physics of Nanostructures, Bielefeld University, Department

of Physics

Inductive power transfer is a well-established technology, e.g. for inductive heating in industrial applications and household appliances like inductions hobs. An inductive heating system usually consists of a coil (transmitter) which is powered by an alternating current and a ferromagnetic material (receiver), for example a cooking vessel. FEM simulations are a powerful tool for simulating the electromagnetic processes in coil and vessel. For electronics development, FEM simulations of the coil cooking vessel system are too computationally intensive.

In electronics, the coil is an RL element and thus is also represented as such in electronics simulations. This equivalent circuit is sufficient for simple considerations, but neglects that R and L are frequency dependent. Frequency dependent variables can be used in the frequency domain only but not in the important time domain simulations with non-sinusoidal signals. In order to consider the frequency dependence of R and L in time domain simulations for non-sinusoidal signals, we use an improved equivalent circuit based on passive components that includes the frequency dependence.

MA 23.49 Tue 17:00 P1

Demistifying exchange mechanisms in the 2D FenGeTe2 family through Wannierization — •Soheil Ershadrad, Sukanya Ghosh, and Biplab Sanyal — Uppsala Univeristy, Uppsala, Sweden

The FenGeTe2 (n=3,4,5) family of 2D ferromagnets features near-room temperature ferromagnetism, making them promising for use in spintronic devices. In these crystals, a metallic film of FenGe is sandwiched between two layers of Te, separated by a van der Waals (vdW) gap. Due to their complex structures, the physics behind their exotic magnetic behavior is not well understood. Using density functional theory, we investigated the magnetic properties of the FenGeTe2 family. Through the projection of Bloch states into Wannier functions, the orbital resolved Heisenberg exchange parameters based on the tight-binding hopping parameters were determined. Based on the extracted hopping parameters, we investigate exchange mechanisms and explain the differences in exchange interactions. Our calculations indicate that the relative position of Ge with respect to Fe atoms has a significant impact on the strength of the exchange, resulting in a strong short-range indirect exchange in the FenGeTe2 structures along with a long-ranged RKKY type of interaction.

MA 23.50 Tue 17:00 P1

Magnon transport in magnetically ordered insulator/platinum nanostructures — •Maria Sigl[1,2], Janine Gückelhorn[1,2], Monika Scheufele[1,2], Franz Weidenhiller[1,2], Matthias Opel[1], Stephan Geprägs[1], Hans Huebl[1,2,3], Matthias Althammer[1,2], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology, München, Germany

For energy-efficient information processing, the transport and manipulation of spin waves (magnons) in magnetically ordered insulators (MOIs) offers a promising route. To this end, we investigate the magnon transport in MOI/Pt bilayers by all-electrical means utilizing the spin Hall effect. Here, we focus on the transport in the ferrimagnet yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG) and the antiferromagnet hematite (α-Fe_2O_3) using two- and three-terminal devices. Two electrically isolated Pt strips on top of the MOI, act as spin current injector and detector. An applied charge current to a third strip, the modulator, in between injector and detector allows for electrical control of the diffusive magnon spin transport. We systematically study the distance and magnetic field dependence of the magnon transport in YIG and hematite and compare our results to simultaneous spin Hall magnetoresistance measurements.

MA 23.51 Tue 17:00 P1

Super-Nyquist-sampling MOKE elucidates the role of interfacial exchange coupling when measuring spin Hall effect in the noncollinear antiferromagnet Mn_3Ir — Piet Urban[1], Rouven Dreyer[1], James M Taylor[1], •Srishti Dongare[1], Binoy K Hazra[2], Stuart S P Parkin[2], and Georg Woltersdorf[1] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, 06120 Halle, Germany

Non-collinear antiferromagnets (AFs) have been found to serve as an efficient source of intrinsic spin Hall effect (SHE). However, the role of their 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 electrically-detected spin-torque ferromagnetic resonance (ST-FMR) and optically-detected super-Nyquist-sampling magneto-optical Kerr effect (SNS-MOKE) measurements, we investigate the SHE generated by the non-collinear spin texture of Mn_3Ir in heterostructures with $Ni_{80}Fe_{20}$. The enhanced damping due to interfacial exchange coupling between the AF and FM complicates extraction of the spin Hall angle (SHA) using ST-FMR. In contrast, spatially-resolved SNS-MOKE studies allow for a local detection of the SHA, and reveal modifications of the coupling-induced anisotropy upon exposure to a combination of DC current and RF power. These findings offer us a path to quantify the SHE generated by an AF more accurately, as well as to control their domain structure in a local manner.

MA 23.52 Tue 17:00 P1

Magneto-optical probing of orbital accumulation in a light metal — •Sanaz Alikhah[1], Marco Berritta[2], Peter M. Oppeneer[1], Igor Lyalin[3], and Roland K. Kawakami[3] — [1]Uppsala University, Uppsala, Sweden — [2]University of Exeter, Exeter, United Kingdom — [3]Ohio State University, Ohio, USA

Orbital currents and orbital accumulation are attractive alternatives to the commonly employed spin counterparts, generated typically by the spin Hall effect in heavy metals. However, the detection of orbital currents and accumulation is a challenging task. Here we investigate theoretically the possibility of magneto-optical (MO) detection of current-induced orbital accumulation in the light metal chromium. Using linear-response theory, we compute, first, the spin and orbital accumulation and then predict the expected MO spectrum for pure spin accumulation or pure orbital accumulation. We find that the orbital Hall effect is much larger than the spin Hall effect, and that the orbital MO response is much larger than that due to the spin polarization. This result opens the door for MO detection of current-induced orbital accumulation. Finally, we compare the computed MO responses with recent MO Kerr effect measurements on chromium.

MA 23.53 Tue 17:00 P1

Spin Hall Magnetoresistance in Hybrid Chiral Molecule / Metal / Magnet Systems — •Simon Sochiera[1], Ashish Moharana[1], Shuanglong Wang[2], Hao Wu[2], Fabian Kammerbauer[1], Maria-Andromachi Syskaki[1], Zijie Qiu[2,3], Tomasz Marszalek[2], and Angela Wittmann[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Max Planck Institute for Polymer Research, Ackermannweg 10, 55128, Mainz, Germany — [3]Shenzhen Institute of Aggregate Science and Technology, School of Science and Engineering, The Chinese University of Hong Kong, 2001 Longxiang Boulevard, Longgang District, Shenzhen City, Guangdong, 518172, China

The high efficiency of spin filtering has propelled chiral molecules to the center of attention in molecular spintronics. In conventional ferromagnet/ heavy-metal heterostructures, the spin Hall magnetoresistance has been established as a highly sensitive probe of the interplay between a charge current and magnetization mediated via spin currents. Here, we investigate the chiral-induced spin selectivity effect by probing the impact of the adsorption of chiral molecules on the spin Hall magnetoresistance of a well-characterized device. The change in the magnetoresistive behavior of the device will give insight into the underlying mechanisms at in hybrid chiral molecule/ metal/ ferromagnet multilayer structures.

MA 23.54 Tue 17:00 P1

2D nearfield imaging of cells with high broadband spintronic THz emitters — •Tristan Winkel, Finn-Frederik Stiewe, Doreen Biedenweg, Oliver Otto, and Markus Münzenberg — Universität Greifswald, Greifswald, Deutschland

Gaining information about cells is very important in many fields of science such as biology and medicine. 2D nearfield imaging of cells with high broadband spintronic THz emitters provides effective means to gain information about the cells. Since measurements are made with broadband teraherz pulses, the absorption spectrum can also be determined for each spatial measurement point. The spatial resolution can reach 5μm with our setup[1]. Among other things, this allows conclusions to be drawn about the water content of the cell. Our technical approach offers great potential for medical applications due to the high gain of information.

[1] Spintronic emitters for super-resolution in THz-spectral

imaging Appl. Phys. Lett. 120, 032406 (2022); https://doi.org/10.1063/5.0076880

MA 23.55 Tue 17:00 P1

THz emission from Ni/NiO/Pt and Co/CoO/Pt multilayers — •Nikos Kanistras[1], Laura Scheuer[2], Dimitrios Anyfantis[3], Panagiotis Poulopoulos[3], and Evangelos Th. Papaioannou[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany — [2]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663, Kaiserslautern, Germany — [3]Department of Materials Science, School of Natural Sciences University of Patras, Rio, 26504 Patras, Greece

Ultrafast spin-to-charge conversion in heterostructures composed of ferromagnetic (FM)/non-magnetic(NM) thin films can give rise to the emission of THz electromagnetic waves[1]. In this work we investigate the role of an antiferromagnetic oxide interlayer like NiO and CoO in the THz emission. The trilayers are grown with the sputtering technique. The samples exhibit in plane magnetic easy axis as revealed by magneto-optical and Squid magnetometry. The presence of very thin NiO and CoO allows the spin transport from the ferromagnetic to the Pt layer and lead to the THz emission. However, there is a reduction on the signal which is discussed in conjunction of the structural and magnetic properties of the antiferromagnetic layers. [1]E. Papaioannou, R. Beigang Nanophotonics10, 1243*1257 (2021).

MA 23.56 Tue 17:00 P1

Investigating spin dynamics in MoS_2/permalloy bilayers — •Rieke von Seggern, Lina Hansen, Jonathan Weber, Christopher Rathje, and Sascha Schäfer — Insitute of Physics, University of Oldenburg, Germany

For the successful integration of spin degrees of freedom in information processing devices, spin-injection into semiconductors plays a crucial role. It was recently demonstrated that an optically generated out-of-equilibrium spin population in a ferromagnetic metal can be efficiently transferred into an adjacent MoS_2 layer across its bandgap [1]. Due to the deflection of the spin current the bilayer then emits electromagnetic pulses in the terahertz (THz) domain analogous to the already established metallic spintronic THz emitters (STE) [2].

In this work, we explore the microscale THz emission properties of single-flake MoS_2/permalloy bilayer systems driven by ultrashort optical pulses (780-nm central wavelength, 70-fs pulse duration). We apply electro-optic sampling to measure the emitted THz electric field in the time domain. An optical excitation spot size in the micrometer range allows for a high spatial resolution of the sample's emission features. With this approach a more detailed understanding of the underlying processes in these TMDC-based samples can be achieved.

[1] Cheng et al., Nat. Phys. 15, 347 (2019)
[2] Seifert et al., Nat. Photonics 10, 483 (2016)

MA 23.57 Tue 17:00 P1

Modulation of exchange bias in Fe3GeTe2/CrPS4 van der Waals heterostructures — Aravind P. Balan[1], •Aditya Kumar[1], Ulrich Nowak[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]Department of Physics, University of Konstanz, Universitätsstraße 10, Konstanz 78464, Germany

Exchange bias (EB) is a well-explored phenomenon in thin film systems. The mechanism of exchange bias in such systems is often associated with defects at the interface. Due to the intrinsic layered structure of the 2D materials, they can be mechanically stacked to form heterostructures with extremely clean and flat interfaces. CrPS4 is an A-type anti-ferromagnet that is stable in an ambient atmosphere. Its out-of-plane anisotropy and layered spin structure make it an ideal anti-ferromagnet for inducing exchange bias in a ferromagnet (FM)/antiferromagnet (AFM) van-der Waal (vdW) heterostructures.[1] In this work exchange bias in Fe3GeTe2 (FGT)/ CrPS4 (CPS) heterostructure has been studied using anomalous hall effect measurements. For a clean FGT/CPS interface, an EB of magnitude 50 mT was observed at 5 K with a blocking temperature of 20 K. Interestingly, the introduction of oxidized FGT at the interface modulates the EB considerably. EB in this system could be induced even without the conventional field-cooling, but by just applying a small pre-set field. References : [1] R. Wu et al., Phys. Rev. Applied 17, 064038 (2022) [2] T. Zhang et al., Advanced Science 9.11, 2105483 (2022)

MA 23.58 Tue 17:00 P1

Quantum transport through 2D metallic magnets: Effects of defects and stacking sequence — Masoumeh Davoudiniya and •Biplab Sanyal — Department of Physics and Astronomy, Uppsala University, Box 516, 751,20 Uppsala, Sweden

In recent times, two-dimensional van der Waals (vdW) bonded magnetic materials with high Curie temperatures have attracted a lot of attraction due to their high potential in future spintronic nanodevices. In this regard, it is important to understand the properties of these magnetic systems even in the presence of several types of defects and stacking of layers, often controlling the properties. Based on density functional theory calculations, this work aims to theoretically address the quantum transport properties of Fe4GeTe2 (FGT) as new 2D vdW layered metallic magnetic materials applicable for the next-generation electronic and magnetic industry. In particular, we investigate the spin-dependent electronic transport through vdW bonded FGT layers connected to Cu electrodes by nonequilibrium Green*s function approach. The influence of the inclusion of Fe atoms in the vdW gap and stacking sequence of layers will be discussed too. Moreover, we will present the studies on the magnetoresistance of the system for different magnetic configurations of FGT layers separated by semimetallic and insulating 2D layers.

MA 23.59 Tue 17:00 P1

Dependence of resistance area product and tunnel magnetoresistance on MgO crystalline quality in CoFeB/ MgO/ CoFeB Magnetic Tunnel Junctions — •Tobias Peters und Günter Reiss — Center for Spinelectronic Materials and Devices, University of Bielefeld, Germany

We investigated the tunnel magnetoresistance (TMR) and resistance area product (RA) in CoFeB/MgO/CoFeB magnetic tunnel junctions (MTJs) grown via sputtering deposition and investigated the influence of MgO crystalline quality. Therefore, the Ar-pressure was varied from 0.004 mbar to 0.14 mbar during the MgO deposition. X-ray diffraction (XRD) measurements performed on pseudo spin valves with 10nm thick MgO reveal the highest (001) oriented crystallographic texture of MgO for an Ar-pressure of 0.08 mbar. This MgO sputtering conditions transfered to exchange biased MTJs provides the best barrier quality, which resulted in the lowest RA (17 $\Omega\mu m^2$) with high TMR ratio (198%) for a MgO thickness of 0.8nm. Additionally we found higher Ar partial pressure (above 0.14 mbar) resulting in amorphous MgO with even lower RA (5 $\Omega\mu m^2$), but with significantly reduced TMR ratio (74%).

MA 23.60 Tue 17:00 P1

Atomic Layer Deposition of Yttrium Iron Garnet (YIG) for 3D Spintronics — •Michaela Lammel[1,2,3], Daniel Scheffler[4], Darius Pohl[5], Peter Swekis[4,6], Sven Reitzig[2], Helena Reichlova[3,4], Richard Schlitz[4], Kevin Geishendorf[1,2], Luise Siegl[2,4], Bernd Rellinghaus[5], Lukas M. Eng[2,7], Kornelius Nielsch[1,2,7,8], Sebastian T. B. Goennenwein[3,4,7], and Andy Thomas[1,4] — [1]IFW Dresden — [2]Institute of Applied Physics, TU Dresden — [3]FB Physik, Universität Konstanz — [4]Institut für Festkörper- und Materialphysik, TU Dresden — [5]DCN, cfaed, TU Dresden — [6]MPI CPfS, Dresden — [7]ct.qmat, TU Dresden — [8]Institute of Materials Science, TU Dresden

Three-dimensional (3D) magnetic structures have recently gained increasing interest in the field of spintronics, since going beyond planar films is expected to lead to a variety of new phenomena. Routes for the fabrication of 3D magnetic insulators are of key importance in order to separately study the magnetic and the electronic response of a given 3D structure. Here, we demonstrate the fabrication of thin films of the magnetic insulator yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG) via atomic layer deposition. To that end we utilize a supercycle approach based on sub-nanometer thin layers of the binary systems Fe_2O_3 and Y_2O_3 with the corresponding atomic ratios. We deposit Y_2O_3/Fe_2O_3 multilayer stacks on $Y_3Al_5O_{12}$ substrates and use a subsequent annealing step to obtain YIG films with a high crystalline quality and magnetic properties comparable to the ones realized via other deposition techniques.

MA 23.61 Tue 17:00 P1

Coupling Strength Controlling Vortex Trajectories' Oscillations in Coupled Vortices Spintronic Oscillator — •Abbass Hamadeh[1], Abbas Koujok[1], Salvatore Perna[2], Steffen Wittrock[3], Vitaliy Lomakin[4], Gregoire de Loubens[5], Olivier Klein[6], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiser-

slautern, Kaiserslautern, Germany — [2]University of Naples Federico II, Naples, Italy — [3]Max-Born-Institute for Nonlinear Optics & Short Pulse Spectroscopy, Berlin, Germany — [4]Center for Magnetic Recording Research, Uni. of California San Diego, La Jolla, California 92093-0401, USA — [5]SPEC, CEA, CNRS, Université Paris-Saclay, 91191 Gif-sur-Yvette, France — [6]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, INAC-Spintec, 38054 Grenoble, France

The magnetic vortex state in nano-magnetic structures is a subject of intensive research since it can be brought into auto-oscillation by spin transfer torque. The coupling of vortices via spin-transfer torque and dipolar fields allows to realize complex non-linear dynamics potentially useful for unconventional computing and data processing. For this purpose, we have studied the auto-oscillating modes of an oscillator based on two coupled vortices in a NiFe/Cu/NiFe nano-patterned stack. The respective system was investigated both experimentally and micro-magnetically for different applied magnetic fields and currents. Experimentally, we observed four qualitatively different configurations of GMR spectra. Our simulations show that these different states can be related to the complex, non-circular motion of the coupled vortices.

MA 23.62 Tue 17:00 P1

Experimental detectability of spin current shot noise — •Luise Siegl[1], Michaela Lammel[1], Akashdeep Kamra[2], Hans Huebl[3,4,5], Wolfgang Belzig[1], and Sebastian T. B. Goennenwein[1] — [1]Department of Physics, University of Konstanz — [2]Condensed Matter Physics Center (IFIMAC) and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain — [3]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [4]TUM School of Natural Sciences, Technische Universität München, Garching — [5]Munich Center for Quantum Science and Technology (MCQST), München

A spin current crossing a ferromagnet-metal interface is accompanied by spin current shot noise. This shot noise is well understood in spin space. However, its experimental detection requires a conversion to an observable quantity. Consideration of the established conversion from a spin current to a charge current enables a quantitative analysis of the entire process. Here, we analyze the challenges of detecting spin current shot noise from an experimental perspective. In detail, we show that in a typical electrically detected spin pumping experiment, the voltage noise originating from the spin current shot noise is orders of magnitude smaller compared to the contribution of the Johnson-Nyquist noise. We quantify the ratio between spin current shot noise and Johnson-Nyquist noise and find that this ratio does not scale favorably with geometry and only depends on intrinsic material parameters. Our results suggest that the detection of spin current shot noise using the spin Hall effect is experimentally at best very challenging.

MA 23.63 Tue 17:00 P1

Strain engineering M, L and P in antiferromagnetic $AFeO_3$ films (A = La, Bi) — •Antonia Rieche, Aurora Diana Rata, Wolfgang Hoppe, and Kathrin Dörr — Martin-Luther-Universität Halle-Wittenberg

Magnetization (M), antiferromagnetic order (L) and ferroelectric polarization (P) are ferroic properties which can be probed and potentially also manipulated with light. A major requirement for this is a successful control over the ferroic domain structures in samples, such that a large averaged value of M (L, P) can be reached. Antiferromagnetic ferrites $AFeO_3$ with weak canted ferromagnetism have revealed fascinating optical properties in bulk (crystal) form, whereas film work is quite limited due to nanoscopic multidomain coexistence in such films. Here, early results of our attempt to optimize such ferrite films for optical experiments are presented. Epitaxial strain controlled by the choice of substrate is employed to direct the structural domain formation in $AFeO_3$ (A = La or Bi) films in a desirable way regarding the magnitude and orientation of ferroic order parameters. The films are grown using pulsed laser deposition (KrF 248 nm) and characterized by x-ray diffraction, magnetization measurements, magnetooptical Kerr effect (MOKE) and scanning probe microscopies.

MA 23.64 Tue 17:00 P1

Optimizing the growth of Mn_3Sn thin films in order to investigate magneto-optical Kerr effect, anomalous Nernst effect, and spin-orbit torque switching — •Anagha Mathew[1,2], Srishti Dongare[1], Atul Pandey[1,2], James M Taylor[1], Binoy K Hazra[2], Stuart SP Parkin[2], and Georg Woltersdorf[1,2] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, 06120 Halle, Germany

Mn_3Sn is a promising candidate material for antiferromagnetic spintronic devices, because of its large magneto-transport responses, such as the anomalous Hall effect (AHE), arising from topological band structure features. For future applications, it is important to be able to efficiently reverse the sense of rotation of its noncollinear spin texture on short timescales via spin torques. Achieving this requires a more detailed understanding of such switching mechanisms, in particular the role of chiral domains. To this end, we have optimized the growth of Mn_3Sn films, to show low coercive field and a large fractional change of AHE during spin-orbit torque switching. In addition, these thin films demonstrate significant magneto-optical Kerr effect and anomalous Nernst effect arising from Berry curvature generated by their noncollinear spin texture. We exploit these measurement techniques to map the chiral domain structure of the Mn_3Sn films in an optical and electro-optical manner, respectively.

MA 23.65 Tue 17:00 P1

Dilution of polar antiferromagnet $Co_2Mo_3O_8$ — •Lilian Prodan[1,2], Irina Filippova[2], Alexander Tsirlin[3], Vladimir Tsurkan[1,2], and Istvan Kezsmarki[1] — [1]Experimental Physics V, Institute of Physics, University of Augsburg, D-86159, Augsburg, Germany — [2]Institute of Applied Physics, MD 2028, Chisinau, R. Moldova — [3]Felix Bloch Institute for Solid-State Physics, Leipzig University, 04103 Leipzig, Germany

Antiferromagnetic materials hold great promise for design of ultra-fast and energy-efficient spintronic devices. To this end, understanding the robustness of crystal and magnetic structures and their manipulation are of high importance. Here, we report the effects of site-selective substitution of Zn^{2+} for Co^{2+} ions on the crystal structure, magnetic and thermodynamic properties of the hexagonal polar antiferromagnet $Co_2Mo_3O_8$. In contrast to the transformation from the antiferromagnetic to a ferrimagnetic state in the isostructural $Fe_2Mo_3O_8$ upon even a small Zn-doping [1], a robust antiferromagnetic behavior is preserved in $Co_{2-x}Zn_xMo_3O_8$ up to $x = 0.55$. We found that in the low doping regime ($x < 0.2$) the Zn^{2+} ions primarily occupy the octahedrally coordinated sites, although at higher doping levels they show a clear preference for occupying the tetrahedral sites [2]. Due to the multiple inter-layer exchange paths, dependent on the different coordination of the Co^{2+} ions, the site-selective substitution is reflected in the non-monotonic variation of the magnetic parameters.

[1] T. Kurumaji, et al., Phys. Rev. X **5**, 031034 (2015).
[2] L. Prodan, et al., Phys. Rev. B **106**, 174421 (2022).

MA 23.66 Tue 17:00 P1

Epitaxial Growth of Magnetic Oxides and their magnetic Coupling — •Akashdeep Akashdeep[1], Sven Becker[1], Mathias Kläui[1,2], and Gerhard Jakob[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]Graduate School of Excellence *Materials Science in Mainz* (MAINZ), Staudingerweg 9, Mainz 55128, Germany

Due to its exceptionally low damping, ferrimagnetic Y3Fe5O12 Y3Fe5O12 (YIG) is the prototypical material for studying magnonic properties. By substituting the non-magnetic yttrium with the temperature-dependent magnetic moment of gadolinium, we can introduce an additional spin degree of freedom in the form of a magnetic compensation point. Here, we grow epitaxial RuO2 films and Y3Fe5O12/Gd3Fe5O12 (YIG/GIG) by pulsed laser deposition and study the magnetic coupling in the heterostructures. The XRD patterns show Laue oscillations and a narrow rocking curve, indicating a smooth surface and interface. From bulk-sensitive magnetometry and surface-sensitive spin Hall magnetoresistance measurements, we can control the heterostructures' magnetic properties by tuning the thickness of the individual layers. These bilayer devices could potentially control the magnon transport analogously to electron transport in giant magnetoresistive devices [1]. The RuO2 is tested for the novel altermagnetism effects[2].

[1] H. Wu et.al.; Phys. Rev. Lett. 120, 097205 (2018) [2] L. Šmejkal et al.; Sci. Adv. 6, 23 (2020)

MA 23.67 Tue 17:00 P1

AI-based Recognition of Numerically Generated Multimode Dispersions — •Paul Schreier[1], Milan Ender[1,2], Pascal Frey[1,2], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Aithericon, Kaiserslautern, Germany

The collective excitation of a magnetic system can lead to the excitation of spin waves. The relation between their wave vector and frequency is described by their dispersion relation. This can be determined by means of micromagnetic simulations. The resulting numerical data give an intensity distribution of all frequency-wave vector combinations. To extract the dispersion relations from these data, peak detection algorithms must be used. Compared to, for example, optical dispersion relations, spin wave dispersion relations are much more complex and non-linear, which makes their extraction from the raw data difficult. For this reason, a Convolutional Neural Network is trained with synthetic data to obtain a robust analysis tool. The network is specialized to classify segments in images. The training data consists of intensity distributions and dispersion relations calculated from micromagnetic simulations. Conventional peak detection algorithms were first applied to simple dispersion relations to generate a base set of training data. Recombination of this data produces a more complex and larger data set that requires very few resources. Compared to conventional peak detection algorithms, the robustness and fault tolerance can be increased by appropriate training. Evaluations based on dispersion relations can thus be automated to a large extent.

MA 23.68 Tue 17:00 P1

Imaging and phase-locking of non-linear spin waves — •Rouven Dreyer[1], Alexander F. Schäffer[1], Hans G. Bauer[2], Niklas Liebing[1], Jamal Berakdar[1], and Georg Woltersdorf[1,3] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Jahnstrasse 23, 96050 Bamberg, Germany — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Non-linear processes are a key feature in the emerging field of spin-wave based information processing and allow to convert uniform spin-wave excitations into propagating modes at different frequencies. Recently, the existence of non-linear magnons at half-integer multiples of the driving frequency has been predicted for $Ni_{80}Fe_{20}$ at low bias fields. However, it is an open question under which conditions such non-linear spin waves emerge coherently and how they may be used in device structures. Usually non-linear processes are explored in the small modulation regime and result in the well known three and four magnon scattering processes. Here we demonstrate and image a class of spin waves oscillating at half-integer harmonics that have only recently been proposed for the strong modulation regime. The direct imaging of these parametrically generated magnons in $Ni_{80}Fe_{20}$ elements allows to visualize their wave vectors. In addition, we demonstrate the presence of two degenerate phase states that may be selected by external phase-locking. These results open new possibilities for applications such as spin-wave sources, amplifiers and phase-encoded information processing with magnons.

MA 23.69 Tue 17:00 P1

Magnetoacoustic excitation of spinwaves in yttrium iron garnet / zinc oxide heterostructures — •Kevin Künstle[1], Finlay Ryburn[2], Michael Schneider[1], Yannik Kunz[1], Vitaliy Vasyuchka[1], Carsten Dubs[3], John Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern — [2]University of Oxford — [3]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Surface Acoustic Waves (SAWs) that operate in the Gigahertz regime with wavelengths on the micrometer scale enable the miniaturization of telecommunication microwave devices. In recent years, the coupling of SAWs with spin waves (SWs) in ferromagnetic metals has proven to be a viable option for the realization of applications like acoustic diodes, as the interaction is intrinsically nonreciprocal [1]. However, the coupling of SAWs with SWs in ferrimagnetic insulators is much less explored. We investigated SAWs excited by interdigital transducers made of Ti/Au, which were deposited on a GGG/YIG structure and covered by a piezoelectric ZnO layer. The ferrimagnetic YIG layer serves as a source for SWs to which the SAWs can couple. We used a vector network analyzer and micro-focused Brillouin light scattering spectroscopy to identify the SAW characteristics in the YIG-based heterostructure. The observed magnetoelastic coupling of SAWs with SWs is highly nonreciprocal.

[1] M. Küß et al., Phys. Rev. Lett. 125, 217203 (2020).

MA 23.70 Tue 17:00 P1

Ultrafast magnetization precession in metallic heterostructures driven by different excitation mechanisms — •Jasmin Jarecki[1], Maximilian Mattern[1], Jan-Etienne Pudell[1,2,3], Michel Hehn[4], Fried Weber[1], Alexander von Reppert[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]European X-Ray Free-Electron Laser Facility, Schenefeld, Germany — [4]Institut Jean Lamour (UMR CNRS 7198), Universite Lorraine, Nancy, France

We study the magnetization precession induced by different excitation mechanisms, i.e. ultrafast demagnetization, temperature dependent anisotropy change and magneto-elastic coupling, in 20 nm Ni films within PtCuNi-heterostructures. The samples are excited by an ultrashort laser pulse from the Pt side and designed such that light does not excite Ni directly. The indirect excitation of the Ni is tailored in different ways: strain waves, heat waves and/or hot electrons. We combine time-resolved x-ray diffraction (UXRD) and magneto-optical Kerr effect measurements (MOKE) under variation of the external field angle to access the strain dynamics and therefore also the energy transfer within the sample and the out-of-plane component of the Ni magnetization. We observe a distinct angle-dependence of the precession amplitude depending on the predominant excitation mechanism. While temperature related effects cause high amplitudes for nearly out-of-plane external fields, recurring strain pulses amplify the amplitudes resonantly around $50°$.

MA 23.71 Tue 17:00 P1

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

This contribution focuses on the behavior of a magnon-Bose–Einstein condensate (BEC) in artificial magnetization landscapes on the scale of wavelengths of condensed magnons. In our work, the magnon condensate is created by overpopulating a magnon gas using parametric microwave pumping. A heating laser combined with a phase-based wave front modulation technique imprints a complex microscopic temperature pattern onto the yttrium-iron-garnet film sample that can be varied in magnitude and intensity. In this way, the spatial saturation magnetization profile is adjusted and acts as an artificial potential for the BEC, affects its dynamics and drives magnon supercurrents and Bogoliubov waves. Since these micro-sized patterns are small compared to the area of BEC formation, it is possible to investigate the BEC in two-dimensional potential landscapes. In the experiment, we use micro-focused Brillouin light scattering spectroscopy to investigate the anisotropy of the two-dimensional density distribution of a magnon BEC and the possibility of interference effects between Bogoliubov waves. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) -TRR 173-268565370 (project B04)

MA 23.72 Tue 17:00 P1

Nonreciprocal microwave transmission enabled by magnon-phonon conversion — •Florian Kraft[1], Yannik Kunz[1], Michael Schneider[1], Matthias Küss[2], Manfred Albrecht[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Universität Augsburg

The magnetoelastic coupling between surface acoustic waves (SAWs) and spin waves (SWs) may enable applications such as miniaturized microwave isolators. The required nonreciprocity can be induced by symmetry breaking coupling mechanisms between phonons and magnons [1]. Here, we investigate nonreciprocal microwave transmission in a device based on the conversion of SAWs, excited by interdigital transducers (IDTs), to SWs, which are detected by a microwave antenna and vice versa. To this end, we use a sample structure made of $LiNbO_3$/Ta(3 nm)/$Co_{40}Fe_{40}B_{20}$(10 nm). We use a setup for combined microwave and optical spectroscopy based on microfocused Brillouin light scattering spectroscopy and vector network analysis. This allows for simultaneous electrical and optical detection of phonon-magnon-interactions. We analyze the nonreciprocal microwave transmission while simultaneously investigating the phonon-magnon-coupling with spatial resolution.

We acknowledge funding by DFG via project No. 492421737.

[1] M. Küß et al., Phys. Rev. Lett. 125, 217203 (2020).

MA 23.73 Tue 17:00 P1

Frequency multiplication by collective nanoscale spin-wave dynamics — •Chris Koerner[1], Rouven Dreyer[1], Martin Wagener[1], Niklas Liebing[1], Hans G. Bauer[2], and Georg Woltersdorf[1,3] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Jahnstrasse 23, 96050 Bamberg, Germany. — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Frequency multiplication is a process in modern electronics in which harmonics of the input frequency are generated in nonlinear electronic circuits. Devices based on the propagation and interaction of spin waves are a promising alternative to conventional electronics. The characteristic frequency of these excitations is in the gigahertz (GHz) range and devices are not readily interfaced with conventional electronics. Here, we locally probe the magnetic excitations in a soft magnetic material by optical methods and show that megahertz-range excitation frequencies cause switching effects on the micrometer scale, leading to phase-locked spin-wave emission in the GHz range. Indeed, the frequency multiplication process inside the magnetic medium covers six octaves and opens exciting perspectives for spintronic applications, such as all-magnetic mixers or on-chip GHz sources.

C. Koerner et al., Science 375, 6585 (2022)

MA 23.74 Tue 17:00 P1

Excitation of propagating spin waves in Ga:YIG thin films — •Moritz Bechberger[1], David Breitbach[1], Björn Heinz[1], Bert Lägel[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

The material parameters of yttrium-iron-garnet (YIG), a well-known material in the research field of magnonics, can be modified by a partial substitution with gallium atoms leading to a lower saturation magnetization. In this study the propagation properties of spin waves in a YIG thin film doped with gallium (Ga:YIG) were investigated and characterized. Direct excitation of coherent spin waves was performed by patterned microantennas and they were detected using TR-BLS microscopy. Our experiments confirm the presence of fast, exchange dominated spin waves, as well as an isotropic spin-wave dispersion relation. In addition, the influence of nonlinear effects on the spin wave excitation was determined. In agreement with the negative effective magnetization of the Ga:YIG film, using high amplitude excitation, we find a positive nonlinear frequency shift for an in-plane magnetization. This results in a significant power-dependent foldover effect, which provides nonlinear power dependencies for the excitation. This study is of high interest for magnonic data processing and reveals novel possibilities for magnonic devices with a tunable nonlinearity. This research is funded by the DFG - Project No. 271741898 and TRR 173-268565370 (B01) and the ERC Grant No. 101042439 'CoSpiN'.

MA 23.75 Tue 17:00 P1

In Stitu Inverse Design for Magnonic Logic Devices — •Malte Koster[1], Philipp Pirro[1], and Georg von Freymann[1,2] — [1]Physics Departement and Research Center OPTIMAS - Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

The need for fast and energy-efficient computing devices is currently a topic of great interest. Magnonic logic devices could offer a promising solution to this need. Due to the intrinsic nonlinearity of spin waves, novel approaches to computation arise in a single logic gate. At the same time, the nonlinear nature makes the design of such devices particularly challenging. We propose a method for inverse design of magnetic logic gates in structured or unstructured yttrium-iron-garnet film samples by using thermal landscapes.

In this design approach, the desired function is specified and the design is modified until it is achieved. The thermal landscapes are created using a laser whose intensity distribution on the sample is arbitrarily modified via a spatial light modulator. The resulting local heating modifies the magnetization landscape. The function of the device is determined using a vector network analyzer. Compared to inverse design via micromagnetic simulations [1], our approach promises significantly higher speed as well as direct proof of functionality in real applications.

[1]Wang, Q et.al. Inverse-design magnonic devices. Nat Commun. **12**, 2636 (2021)

MA 23.76 Tue 17:00 P1

Microwave Control of Magnon Transport and Spin Pumping in Nanostructures — •Franz Weidenhiller[1,2], Janine Gückelhorn[1,2], Manuel Müller[1,2], Korbinian Rubenbauer[1,2,3], Hans Huebl[1,2,3], Matthias Althammer[1,2], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology, München, Germany

Magnon transport in magnetically ordered insulators is of great interest for the implementation of magnonic devices. Here we report our results on the diffusive magnon transport in yttrium iron garnet (YIG) and its control by the simultaneous excitation of magnons with electromagnetic microwaves. Using e-beam lithography, we pattern two platinum (Pt) strips on top of the YIG for the injection and detection of magnons. The Pt strips are electrically insulated from an aluminum microwave antenna, which covers both strips and the gap in between. Via the antenna, microwave-driven generation of magnons in the active device area by parallel and perpendicular pumping is possible. Our proposed device geometry allows us to distinguish these two pumping contributions in the acquired signal. We investigate how these microwave injected magnons affect the magnon transport between the two Pt strips. Moreover we study the spin pumping signal at different magnetic fields, microwave frequencies and powers. Finally, we discuss relevant magnon relaxation mechanisms in our experiments.

MA 23.77 Tue 17:00 P1

Elementary magnetic excitations in epitaxial strained Sr_2IrO_4 thin films probed by resonant inelastic X-ray scattering — •Herman Muzychko[1,2], Monika Scheufele[1,2], Dan Mannix[3,4], Stephan Geprägs[1], and Rudolf Gross[1,2,5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]European Spallation Source, Lund, Sweden — [4]Institut Néel, CNRS, Grenoble, France — [5]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

The Ruddlesden-Popper series $Sr_{n+1}Ir_nO_{3n+1}$ has attracted considerable scientific attention due to the possibility of generating new physics properties within a strong spin-orbit coupling regime. In the first member of the series, the layered Sr_2IrO_4 (SIO) compound, the large spin-orbit coupling combined with a moderate Coulomb repulsion results in a Mott insulating $J_{\mathrm{eff}} = 1/2$-ground state, which is similar to the $S = 1/2$-ground state of high-T_c superconducting Cu oxides. By performing resonant inelastic X-ray scattering (RIXS) experiments, we have investigated the elementary magnetic excitations in epitaxial strained-SIO thin films. The thus obtained spin wave dispersions have been simulated within the linear-spin wave theory by using the program package SpinW. With this, we are able to resolve the effect of epitaxial strain [1] on the elementary magnetic excitations in SIO by comparing our results to bulk SIO spin wave properties.

[1] S. Geprägs *et al.*, Phys. Rev. B **102**, 214402 (2020).

MA 23.78 Tue 17:00 P1

Spontaneous emergence of spin-wave frequency combs mediated by vortex gyration — •Christopher Heins[1,2], Katrin Schultheiss[1], Lukas Körber[1,2], Attila Kákay[1], Tobias Hula[1,3], Mauricio Bejarano[1,2], Jürgen Lindner[1], Jürgen Fassbender[1,2], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Fakultät Physik, Technische Universität Dresden, Dresden, Germany — [3]Institut für Physik, Technische Universität Chemnitz, Chemnitz, Germany

We present experimental investigations of spin-wave frequency combs forming in a confined system, a magnetic vortex. The magnetic vortex shows rich spin-wave dynamics with frequencies in the GHz range, which can be harnessed for pattern recognition [1]. Additionally, there is the low frequency gyration of the vortex core itself. The combination of these dynamics on two different time scales inside magnetic vortices, results in the generation of spin-wave frequency combs with their spacing given by the vortex gyration frequency. Using time-resolved Brillouin light scattering microscopy, we show that large amplitude excitations of spin waves purely in the GHz range can induce a gyration of the vortex core and vice versa, which leads to the formation of frequency combs.

The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within program SCHU 2922/1-1.

[1] L. Körber, et al., arXiv preprint arXiv:2211.02328 (2022).

MA 23.79 Tue 17:00 P1

Manipulation of spin-waves dynamics in two-sublattice antiferromagnet by an electric field — •Olha Boliasova[1,2] and Vladimir Krivoruchko[2] — [1]Leibniz Institute for Solid State and Materials Research Dresden, Dresden, Germany — [2]Donetsk Institute for Physics and Engineering named after O.O. Galkin, Kyiv, Ukraine

Spin waves are one of the promising candidates for information carriers in future electronic devices. They are applicable in the wide frequency region and reduce energy losses. Now the main challenge is to uncover mechanisms of proper propagation, manipulation, and detection of spin waves. Recent research shows that a magnetic and electric field could manipulate spin dynamics. The last variant opens the possibility to realize different propagation spin-waves in opposite directions, not limited to the magnets with inversion symmetry breaking. It is possible as an external electric field could induce the Dzyaloshinskii-Moriya interaction that changes the spatial distribution of spin waves in the nonchiral magnets. Confirmation of this is already available for ferromagnets, and we provide more in-depth studies of this effect for a two-sublattice antiferromagnet. We use a phenomenological approach based on the Landau-Lifshitz-Gilbert equations to detect spin dynamics. The dependence of spin dynamics on the magnitude of the applied electric field was found.

MA 23.80 Tue 17:00 P1

Undirectional spin wave propagation mediated by $Co_{25}Fe_{75}$- and $Ni_{80}Fe_{20}$-nanogratings — •Monika Scheufele[1,2], Christian Mang[1,2], Manuel Müller[1,2], Johannes Weber[1,2], Vincent Haueise[1,2], Hans Huebl[1,2,3], Matthias Althammer[1,2], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

The unidirectional propagation of spin waves provides novel functionalities for magnonic logic devices. Here, we report the fabrication of $Co_{25}Fe_{75}$ (CoFe)- and $Ni_{80}Fe_{20}$ (Py)-nanogratings via electron beam lithography and DC magnetron sputtering on yttrium iron garnet (YIG) and CoFe thin films, respectively. The dipolar magnetic coupling between the nanogratings and the continuous thin films induces a finite nonreciprocity of the spin wave propagation if the magnetization within the gratings and the thin films is collinear [1]. By performing broadband ferromagnetic resonance as well as spin wave spectroscopy, we study the coupled spin wave modes in these magnonic devices. Moreover, we compare the properties of the CoFe/YIG and Py/CoFe platforms and also compare them with micromagnetic simulations.

[1] J. Chen *et al.*, Phys. Rev. B **100**, 104427 (2019).