MA 19: Poster 1

Topics: Skyrmions (MA 19.1-19.8), Non-Skyrmionic Magnetic Textures (MA 19.9-19.10), Caloric Effects in Ferromagnetic Materials (MA 19.11-19.15), Spin Calorics (general)(MA 19.16-19.17), Molecular Magnetism (19.18-19.22), Biomagnetism, Biomedical Applications (MA 19.23), Electron Theory of Magnetism and Correlations (MA 19.24), Magnetic Imaging Techniques (MA 19.25-19.29), Neuromorphic Magnetism / Magnetic Logic (MA 19.30-19.31), Computational Magnetism (MA 19.32-19.38), Spin Transport and Orbitronics, Spin-Hall Effects (MA 19.39-19.45), Terahertz Spintronics (MA 19.46-19.54), Spin-Dependent Phenomena in 2D (MA 19.55-19.56), Spintronics (other effects) (MA 19.57-19.61), Functional Antiferromagnetism (MA 19.62-19.64).

Time: Tuesday 17:30–20:00 Location: P2

MA 19.1 Tue 17:30 P2

Magnetic states in the FeGe nanocylinder — •Andrii Savchenko[1,2], Fengshan Zheng[3,4], Nikolai Kiselev[1], Luyan Yang[3], Filipp Rybakov[5], Stefan Blügel[1], and Rafal Dunin-Borkowski[3] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Donetsk Institute for Physics and Engineering, NAS of Ukraine, 03028 Kyiv, Ukraine — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Spin-X Institute, School of Physics and Optoelectronics, State Key Laboratory of Luminescent Materials and Devices, Guangdong-Hong Kong-Macao Joint Laboratory of Optoelectronic and Magnetic Functional Materials, South China University of Technology, Guangzhou 511442, China — [5]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden

Magnetic states in a nanocylinder of B20-type FeGe are studied using off-axis electron holography and micromagnetic simulations [1]. Considering the presence of a damaged layer on the surface of the nanocylinder, which results from focused ion beam milling during sample preparation, we achieved a quantitative agreement between experimental and theoretical images. Remarkably, we identified one of the experimentally observed states as a dipole string composed of two Bloch points of opposite topological charge. 1. A.S. Savchenko et al., arXiv:2205.05753.

MA 19.2 Tue 17:30 P2

Imaging magnetization dynamics in ferromagnetic multilayer systems with Dzyaloshinskii-Moriya interaction, modified by local He+ irradiation — •Arne Vereijken[1], Sapida Akhundzada[1], Florian Ott[1], Maxwell Li[2], Tim Mewes[3], Arno Ehresmann[1], Vincent Sokalski[2], and Michael Vogel[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

The Dzyaloshinskii-Moriya interaction (DMI) is an asymmetric exchange interaction[1,2] promoting chiral coupling between spins, giving rise to robust, chiral, topological spin textures, e.g., skyrmions with outstanding properties for information storage and processing[3]. DMI may originate, e.g., from the interface between a ferromagnet and a heavy metal. Recently it has been demonstrated that the DMI at such interfaces can be tuned by irradiation with keV He+ ions[4]. In a systematic study, we investigated the influence of local He+ ion irradiation on the magnetization dynamics in a perpendicularly magnetized ferromagnetic/heavy metal multilayer system by high-resolution magneto-optical Kerr-microscopy. [1] T. Moriya, Phys. Rev. Lett. 4, 228 (1960) [2] I. E. Dzyaloshinskii, J. Phys. Chem. Solids 4(4), 241-255 (1958) [3] C. Back et al, J. Phys. D: Appl. Phys. 53 363001 (2020) [4] H. T. Nembach, et al., Int. J. Appl. Phys. 131, 143901 (2022)

MA 19.3 Tue 17:30 P2

Limits of skyrmion detection — •Hauke Lars Heyen[1], Jakob Walowski[1], Malte Römer-Stumm[2], Markus Münzenberg[1], and Jeffrey McCord[2] — [1]Institut für Physik, Universität Greifswald, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany — [2]Christian-Albrechts-Universität zu Kiel, Institute for Materials Science, Nanoscale Magnetic Materials and Magnetic Domains, 24143 Kiel, Germany

Skyrmion detection is an important feature for the implementation in storage media like e.g. racetrack memory. Kerr microscopy is well suited for the detection of skyrmions on the micrometer scale, but can not be miniaturised down to the nanometer scale. To compete with established storage media methods, miniaturisation of detection methods is essential. Magnetic tunnel junctions (MTJ) are a promising tool to detect small magnetisation changes.

The selected Ta/CoFeB/MgO material system allows to build MTJs integrated into tracks in which skyrmions can be generated and moved along using current pulses. This integration of MTJs into skyrmion racetracks remains challenging, even though they work fine independently. We employ Kerr microscopy to investigate the influence of MTJs on the skyrmion generation and propagation.

MA 19.4 Tue 17:30 P2

Exchange- and Dzyaloshinskii-Moriya interactions in magnetic multilayers at surfaces — •Tim Drevelow, Mara Gutzeit, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany

The coupling of magnetic skyrmions in synthetic antiferromagnets leads to a significant reduction of skyrmion Hall effect and therefore enhanced transports properies [1]. We investigate antiferromagnets based on Rh/Fe and Rh/Co bilayers on an Ir(111) surface, which have previously been grown on this surface [2,3]. With an additional magnetic layer of Fe or Co, we find that these systems realize a synthetic antiferromagnet as a potential host for magnetic skyrmions. Considerations on the symmetry of magnetic states in multilayer systems allow to compute both exchange and Dzyaloshinskii-Moriya interactions within and in between the magnetic layers with *ab initio* calculations using density functional theory.

[1] Zhang *et al.* Nat. Com. **7**, 10293 (2016)
[2] Romming *et al.* Phys. Rev. Lett. **120**, 207201 (2018)
[3] Meyer *et al.* Nat. Com. **10**, 3823 (2019)

MA 19.5 Tue 17:30 P2

High-resolution in-situ mapping of magnetization dynamics — •Arsha Thampi[1,2], Felix Lucas Kern[1], Yejin Lee[1], Daniel Wolf[1], Andy Thomas[1,2], and Axel Lubk[1,2] — [1]Leibniz IFW Dresden, D-01069 — [2]Institute for Solid State and Materials Physics, TU Dresden, D-01069

Mapping of magnetization dynamics at the nanometer scale, which includes domain wall motion and also study on magnetic textures like skyrmions, is performed with time resolved measurements using transmission electron microscopy (TEM). On-chip microsized magnetic charged particle optical elements were developed for spatiotemporal electron beam modulation. The employed micro-coils with a diameter of about 80 μm are combined with soft-magnetic cores and arranged as dipoles and quadrupoles. These micro-electromagnets can generate alternating magnetic fields of about $\pm$100 mT up to hundred MHz. They supply sufficiently large optical power and high-frequent beam manipulation to perform stroboscopic imaging. We discuss stroboscopic magnetization dynamics measurement employing either fast beam blanking or fast focusing. In order to study dynamics of magnetic structures, short electric pulses are applied by means of a sample holder that passes high frequencies. Current driven domain wall motion by spin torque effect is observed in a Nickel system by Lorentz TEM. The shift in domain walls is quantitatively analyzed depending on the current density and the heat deposited on the system. High-resolution mapping of magnetization dynamics can open the way to understand more on defects or pinning sites of domain wall.

MA 19.6 Tue 17:30 P2

Spin dynamics of skyrmion lattices in a chiral magnet re-

solved by micro-focused Brillouin light scattering — Ping Che[1], •Riccardo Ciola[2], Markus Garst[2], Arnaud Magrez[1], Helmuth Berger[1], Thomas Schönenberger[1], Henrik Rønnow[1], and Dirk Grundler[1] — [1]École Polytechnique Fédérale de Lausanne, Lausanne (CH) — [2]Karlsruhe Institute of Technology, Karlsruhe (DE)

Chiral magnets provide an innovative framework to study non-collinear spin textures and their associated magnetization dynamics. They include helical and conical magnetic textures that are spatially modulated with a wavevector k_h, as well as the topologically non-trivial skyrmion lattice (SkL) phase. So far, different techniques have been used to probe the magnetization dynamics of the latter SkL phase both in the small wavevector limit, $k << k_h$, as well as for $k > k_h$. Here, we show that Brillouin light scattering (BLS) is ideally suited to probe the complementary range of wavevectors $k \lesssim k_h$. We study both theoretically and experimentally BLS from bulk spin waves in the SkL phase of Cu_2OSeO_3. We provide parameter-free predictions for the BLS cross section and compute both the resonances and their spectral weight. The theoretical results are compared to BLS experiments in the backscattering geometry that probe magnons with a wavevector $k = 48/\mu m < k_h = 105/\mu m$. The clockwise, counterclockwise and breathing modes are clearly resolved. Due to the finite wavevector of the magnon excitations, finite spectral weight is theoretically predicted also for other resonances. Experimentally, at least one additional resonance can be identified.

MA 19.7 Tue 17:30 P2

Interplay of moderate magnetocrystalline anisotropies and skyrmion lattice order in $Fe_{1-x}Co_xSi$ — •Denis Mettus[1], Grace Causer[1], Alfonso Chacon[1], Andreas Bauer[1], Christian Franz[1], Anna Sokolova[2], Sebastian Mühlbauer[3], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights NSW 2234, Australia — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany

Cubic chiral magnets exhibit a universal magnetic phase diagram due to a hierarchy of energy scales comprising exchange interactions, Dzyaloshinsky-Moriya spin-orbit coupling and magnetocrystalline anisotropies (MCAs). In MnSi thermal Gaussian fluctuations stabilize a skyrmion lattice phase near T_c for all magnetic field orientations reflecting very weak MCAs [1,2]. In Cu_2OSeO_3, an additional skyrmion lattice phase stabilizes in the low temperature limit due to strong MCAs for magnetic field parallel ⟨100⟩ [3]. We report a study of the interplay of moderate MCAs and disorder in $Fe_{1-x}Co_xSi$. Combining magnetometry and small-angle neutron scattering we observe a wide parameter range in which the effects of thermal fluctuations, MCAs and disorder stabilize skyrmion lattice order over an exceptionally wide parameter range depending on field orientation.

[1] S. Mühlbauer et al., Science **323** 915 (2009); [2] T. Adams et al., Phys. Rev. Lett. **121** 187205 (2018); [3] A. Chacon et al., Nat. Phys. **14** 936 (2018).

MA 19.8 Tue 17:30 P2

Interactions between magnetic skyrmions — •László Udvardi[1,2] and Mátyás Török[1] — [1]Budapest University of Technology and Economics, Budapest Hungary — [2]MTA-BME Condensed Matter Research Group, Budapest, Hungary

Recently magnetic skyrmions received considerable attention due to their potential in spintronic devices. Magnetic properties of skyrmions are often described by a classical Heisenberg model with tensorial couplings. We have developed a conjugate gradient method to find the local minima of the energy of a classical spin system. By analyzing the energy of an isolated skyrmion and of pair of skyrmions in the case of FePd bilayer on Ir(111) substrate[1] interactions can be derived as a function of the separation of the skyrmions. The knowledge of the pair interactions permits us to perform Monte Carlo simulations treating skyrmions as quasi particles.

1. Phys. Rev. B 93, 024417 (2016)

MA 19.9 Tue 17:30 P2

Realization of Shankar Skyrmions in magnetically frustrated platforms. — •Steven Schoenmaker, Ricardo Zarzuela, and Jairo Sinova — Johannes Gutenberg University, Mainz, Germany

Three-dimensional magnetic solitons are gathering momentum in the last few years due to their intrinsic complexity and their potential use in topological computing and high-density memory storage. For instance, recent advances have led to the experimental observation of hopfions [1] and skyrmion strings [2] in collinear magnets. Shankar skyrmions [3], the condensed matter realization of skyrmions present in baryonic matter and of which magnetic skyrmions are a two-dimensional analog, can emerge in spin systems described by a SO(3)-order parameter, such as frustrated magnets (namely, magnetic systems with frustrated interactions dominated by isotropic exchange) [4]. Motivated by this possibility, we propose phenomenological and exactly solvable models for Shankar skyrmions in magnetically frustrated spintronic platforms and we also explore whether these topological textures form a crystal phase.

[1] N. Kent et al., Nat. Comms. 12, 1562 (2021).
[2] T. Yokouchi et al., Sci. Adv. 4, eaat1115 (2018);
S. Seki et al., Nat. Comms. 11, 256 (2020).
[3] R. Shankar, J. Physique 38, 1405 (1977).
[4] R. Zarzuela, H. Ochoa and Y. Tserkovnyak, Phys. Rev. B 100, 054426 (2019).

MA 19.10 Tue 17:30 P2

Exploring the limitations of the micromagnetic framework with a stable Bloch point — •Thomas Brian Winkler[1], Marijan Beg[2], Martin Lang[3,4], Mathias Kläui[1], and Hans Fangohr[3,4] — [1]Institut für Physik, JGU Mainz — [2]Department of Earth Science and Engineering, Imperial College London — [3]Faculty of Engineering and Physical Sciences, University of Southampton — [4]Max Planck Institute for the Structure and Dynamics of Matter Hamburg

Bloch points [1,2] are well-known magnetisation configurations that often occur in transient processes. However, recent simulations have shown that opposing chiralities of layers in a thin-film geometry can stabilise such magnetic Bloch points and make them equilibrium states [3], potentially opening the door towards Bloch point based spintronic applications [4]. An open question, from a methodological point of view, is whether the Heisenberg model approach (atomistic model) must be used to study such systems or if the – computationally more efficient – micromagnetic models can be used as well. In this work, we are investigating and comparing the energetics and dynamics of a stable Bloch point [3,4] obtained using both Heisenberg and micromagnetic approaches.

[1] Ricardo Gabriel Elías et al., Eur. Phys. J. B 82, 159-166 (2011). [2] Oleksandr V. Pylypovskyi et al., Phys. Rev. B 85, 224401 (2012). [3] Marijan Beg et al., Scientific Reports 9, 7959 (2019). [4] Martin Lang et al., Bloch points in nanostrips, arxiv:2203.13689 (2022).

MA 19.11 Tue 17:30 P2

Magnetocaloric effect in (La, Ce)(Fe, Si, Mn)$_{13}$ with tunable, low transition temperature — •M. Strassheim[1,2], C. Salazar Mejia[1], J. Wosnitza[1,2], and T. Gottschall[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

The La(Fe, Si)$_{13}$ family is one of the most promising group of magnetocaloric materials due to their overall good cost-benefit ratio in comparison to alloys based on scarce rare-earths such as Gd or Ho. By partly substituting La with Ce and Fe with Mn, the point of the metamagnetic transition can be tuned down to at least 40 K, while maintaining a rather sharp transition to enable a notable magnetocaloric effect. Tuning the magnetocaloric effect down to these temperatures opens up large-scale applications such as the magnetic liquefaction of hydrogen. In this work, we synthesized $(La_{1-z}Ce_z)(Fe_{0.88-y}Mn_ySi_{0.12})_{13}$ with z = 0 . . . 0.4, y = 0 . . . 0.04 and determined the adiabatic temperature change in pulsed magnetic fields. For some samples, we calculated the magnetic entropy change using isothermal magnetization measurements.

MA 19.12 Tue 17:30 P2

Chemical Ordering and Phase Transition in all-d-metal Heusler alloy NiCoMnTi — •David Koch[1], Benedikt Beckmann[1], Olga Miroshkina[2], Nuno M. Fortunato[1], Markus Gruner[2], Hongbin Zhang[1], Oliver Gutfleisch[1], and Wolfgang Donner[1] — [1]Institute of Material Science, Technical Univeristy of Darmstadt, 64287 Darmstadt Germany — [2]Faculty of Physics and Center of Nanointegration, University of Duisburg-Essen, 47057 Duisburg Germany

Chemical ordering in NiMn-based Heusler alloys with magnetostructural phase transition is crucial for understanding the physics of the phase transition and is known for influencing the properties of the alloys. In the new field of all-d-metal Ni(Co)MnTi Heusler alloys, the experimental determination of chemical order is challenging due to the low difference in scattering power of the different elements. Here we report a combined approach of neutron and x-ray diffraction for an analysis of chemical order in Ni(Co)MnTi alloys and show that no Heusler-typical L21 order between Ti and Mn is present. Furthermore, Co and Ni atoms do not exhibit order among them; however, the martensitic phase transition and Curie temperature of Co containing samples can be shifted signifcantly by changing the degree of B2 order with a proper heat treatment. Using first-principles calculations, we reveal how the structural and magnetic sub-systems depend on the degree of B2 disorder. An outlook to further experiments on single crystals is given.

MA 19.13 Tue 17:30 P2

Simultaneous measurements of magnetocaloric materials in pulsed magnetic fields — •Tino Gottschall[1], Eduard Bykov[1,2], Marc Strassheim[1], Timo Niehoff[1,2], Catalina Salazar-Mejia[1], and Jochen Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

The direct determination of the adiabatic temperature change as a function of magnetic field and starting temperature is of central importance for a profound characterization of magnetocaloric materials. Recently, we developed a technique to measure the temperature change in pulsed magnetic fields directly and simultaneously also other properties such as strain and magnetization can be determined. In this work, we give an overview of the most recent results that have been obtained in pulsed fields at the Dresden High Magnetic Field Laboratory. This work was supported by HLD at HZDR, member of the European Magnetic Field Laboratory (EMFL) and the Helmholtz Association via the Helmholtz-RSF Joint Research Group Project No. HRSF-0045.

MA 19.14 Tue 17:30 P2

Tuning the magnetocaloric phase transition of La(Fe,Si)$_{13}$ by rare earth doping — •Johanna Lill[1], Benedikt Eggert[1], Benedikt Beckmann[2], Olga N. Miroshkina[1], Iliya Radulov[2], Konstantin Skokov[2], Jose R. Linares Mardegan[3], Sonia Francoual[3], Richard Brand[1], Katharina Ollefs[1], Markus E. Gruner[1], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]University of Duisburg-Essen, Duisburg, Germany — [2]TU Darmstadt, Darmstadt, Germany — [3]DESY, Hamburg, Germany

Magnetocaloric (MC) materials are promising environmentally friendly candidates to replace gas-compression refrigerants. There are many MC systems possessing a high MC effect by showing high adiabatic temperature or isothermal entropy changes, but goals are still to minimize hysteresis and to tune the phase transition (PT) temperature to room temperature (RT). Therefore, knowledge of electronic and magnetic interactions in different magnetic phases are essential, as these determine the PT properties. One promising MC material is La(Fe,Mn,Si)$_{13}$H, which has its PT temperature around RT after hydrogenation, stabilized by Mn-doping which increases thermal hysteresis. To tune its thermal hysteresis, we study the effect of rare earth doping in the (La,Ce,Nd)(Fe,Si)$_{13}$ system and systematically investigate local electronic and magnetic properties in the different magnetic states utilizing e.g. XMCD and Mössbauer spectroscopy. With this study we present a deepened understanding of tuning local properties which may open new ways for tailoring hysteresis of MC materials. We acknowledge financial support from DFG through TRR270 HoMMage.

MA 19.15 Tue 17:30 P2

Insights into the magnetic structure of Mn-doped La(Fe,Si)$_{13}$ — •Benedikt Eggert[1], Johanna Lill[1], Olga N. Miroshkina[1], Konstantin Skokov[1], Katharina Ollefs[1], Markus E. Gruner[1], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Functional Materials, TU Darmstadt

Magnetic cooling has the potential to replace conventional gas compression refrigeration. Here, materials such as FeRh, NiMn-based Heusler alloys or La(Fe,Si)$_{13}$ exhibit a sizeable first-order magnetocaloric effect To further optimize the efficiency, it is necessary to tune the phase transition close to room temperature and reduce the thermal hysteresis. For La(Fe,Si)$_{13}$, it was shown that it is possible to tailor the phase transition towards room temperature by interstitial H-doping, while maintaining first-order character. In addition, Mn doping allows fine tuning of Tc to enlarge to temperature window of operation, inducing also second-order features. We discuss variations of the electronic and geometric structure in La(Fe,Si)$_{13}$ with increasing Mn content by means of Mössbauer spectroscopy. Mössbauer measurements reveal a reduction of the Fe magnetic moment with increasing Mn concentration. A reduction and broadening of the hyperfine field distribution occurs for higher Mn-content, while in-field measurements indicate a non-colinear spin structure for high Mn-concentrations.
We acknowledge the financial support through the Deutscheforschungsgemeinschaft wihtin the framework of the CRC/TRR270 HoMMage.

MA 19.16 Tue 17:30 P2

Thermally generated spin transport in Fe_3O_4/NiO/Pt trilayers — •Johannes Demir[1], Stefan Becker[1], Paula Bunte[1], Lennart Schwan[2], Olga Kuschel[3], Joachim Wollschläger[3], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]Bielefeld University of Applied Sciences, Germany — [3]Osnabrück University, Germany

We investigate the spin Seebeck effect (SSE) in Fe_3O_4/NiO/Pt trilayers by varying the thickness of the antiferromagnetic NiO layer from 0 to 20 nm. Furthermore, we compare the SSE voltage normalized to the temperature difference to literature [1] and to the experimentally detected heatflux [2]. The Fe_3O_4/NiO bilayer is grown in situ by molecular-beam epitaxy, while the Pt layer is deposited ex situ by DC sputtering. We see an enhanced spin current signal in 0.5 and 1.1 nm NiO on 48 nm Fe_3O_4 for both normlizations. Moreover, we recognize a deviation from the simple exponential behaviour above 9.5 nm NiO thickness indicating a generation of spin current in NiO detectable for larger NiO thickness. Additionally, we simulate the temperature gradient in Fe_3O_4 in an equivalent circuit model depending on the NiO thermal conductivity and the interface thermal conductances to examine the influence of the thermal depth profile of the NiO layer on the thermally induced spin current.

[1] L. Baldrati et al., Phys. Rev. B 98, 014409 (2018)
[2] A. Sola et al., Sci. Rep. 7, 46752 (2017)

MA 19.17 Tue 17:30 P2

Systematic variation of $NiFe_2O_4$ thin film lattice parameters by post-annealing in oxygen atmosphere — •Julian Strassburger, Jan Biedinger, Oliver Ritter, Tobias Peters, Luca Marnitz, Karsten Rott, and Timo Kuschel — Center for Spineletronic Materials and Devices, Bielefeld University, Germany

Nickel ferrite (NFO) is a ferrimagnetic insulator and a promising material for spin caloric applications [1,2,3]. In this study, twin samples of NFO thin films (45nm thick) were prepared on $MgAl_2O_4$ substrates by reactive DC magnetron sputter deposition. The samples were in-situ post-annealed in oxygen atmosphere at different temperatures. After cooling down to room temperature, one sample of each pair was capped by 3nm of Pt for future spin Seebeck effect studies. It was shown by x-ray diffraction analysis that the in-plane and out-of-plane lattice constants change systematically by varying the post-annealing temperature. A possible change of oxygen content in the samples was investigated by determining the unit cell volume and Possion's ratio from the lattice parameters as well as the optical band gap energy from optical spectroscopy data [4,5]. In a next step, the influence of systematically modified lattice parameters on thermally induced spin transport will be investigated.

[1] D. Meier et al., Phys. Rev. B 87, 054421 (2013)
[2] C. Klewe et al., J. Appl. Phys. 115, 123903 (2014)
[3] D. Meier et al., Nat. Commun. 6, 8211 (2015)
[4] P. Bougiatioti et al., Phys. Rev. Lett. 119, 227205 (2017)
[5] P. Bougiatioti et al., J. Appl. Phys. 122, 225101 (2017)

MA 19.18 Tue 17:30 P2

The origin of S-shaped magnetizations and why the connection to toroidal moments is misleading — •Dennis Westerbeck, Daniel Pister, and Jürgen Schnack — Universität Bielefeld, D-33501 Bielefeld, Deutschland

Recent studies for toroidal molecules suggest a connection between low-lying toroidal states and an S-shaped magnetization [1]. We show that for theoretical models the S-shape neither is an evidence for a toroidal moment nor do all toroidal systems form S-shaped magnetizations [2]. Instead, the shape of magnetization curve is a result of a combination of strong anisotropies with spin-spin interactions blocking a spin flip for weak magnetic fields. The phenomenon also strongly depends on the spin quantum numbers. Toroidal moments even can be transformed to zero, if no additional anisotropic interactions between spins are taken into account.

[1] K. R. Vignesh, Nat. Commun. 8, 1023 (2017)

[2] J. M. Ashtree, Eur. J. Inorg. Chem. 2021 (5), 435 (2021)

MA 19.19 Tue 17:30 P2

X-ray absorption and differential reflectance spectroscopies of spin-crossover molecules on HOPG — •Jorge Torres[1], Sascha Ossinger[2], Sangeeta Thakur[1], Clara W.A. Trommer[2], Marcel Walter[1], Ivar Kumberg[1], Rahil Hosseinifar[1], Evangelos Golias[1], Sebastien Hadjadj[1], Jendrik Gördes[1], Pin-Chi Liu[1], Chen Luo[3], Lalminthang Kipgen[1], Tauqir Shinwari[1], Florin Radu[3], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Freie Universität Berlin, Institut für Experimentalphysik, Berlin, Germany — [2]Christian-Albrechts-Universität zu Kiel, Institut für Anorganische Chemie, Kiel, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

In order to use visible light to observe the switching between the high spin (HS) and low spin (LS) state of a $[Fe\{H_2B(pzpy)pz\}_2]$ [1] spin-crossover molecule (SCM), a sub-monolayer was deposited on highly oriented pyrolytic graphite (HOPG) and the sample temperature varied from 120 to 350 K. The difference in light reflection between the pristine HOPG and the SCM sub-monolayer was analyzed by differential reflectance spectroscopy (DRS). Furthermore, the total HS fraction obtained from X-ray absorption spectroscopy (XAS) at temperatures ranging from 10 to 350 K was compared to the DRS absorption spectra. A systematic absorption in the UV region shows that the intensity is proportional to the temperature. Here, the ligand-centered absorption is stronger than the metal-to-ligand charge transfer, making this SCM a promising candidate for optically switched storage devices at room temperature. [1] S. Ossinger, Inorg. Chem., 2020, 59, 7966-7979

MA 19.20 Tue 17:30 P2

Spin-phonon interaction and tunnel splitting in single-molecule magnets — •Kilian Irländer[1], Jürgen Schnack[1], and Heinz-Jürgen Schmidt[2] — [1]Fakultät für Physik, Universität Bielefeld, Postfach 100131, D-33501 Bielefeld, Germany — [2]Fachbereich Physik, Universität Osnabrück, D-49069 Osnabrück, Germany

Quantum tunneling of the magnetization is a phenomenon that impedes the use of small anisotropic spin systems for storage purposes even at the lowest temperatures.

Phonons, usually considered for relaxation of the magnetization over the anisotropy barrier, also contribute to magnetization tunneling for integer spin quantum numbers.

In this context, it is not viable to consider phonons perturbatively but to treat spins and phonons on the same footing by performing quantum calculations of a Hamiltonian where the single-ion anisotropy tensors are coupled to harmonic oscillators.

We demonstrate the ability of phonons to induce a tunnel splitting of the ground doublet which then reduces the required bistability due to Landau-Zener tunneling of the magnetization [1].

We also present the unexpected observation that certain spin-phonon Hamiltonians are robust against the opening of a tunneling gap, even for strong spin-phonon coupling. The key to understanding this phenomenon is provided by an underlying supersymmetry that involves both spin and phonon degrees of freedom [2].

[1] K. Irländer, and J. Schnack, Phys. Rev. B 102, 054407 (2020).
[2] K. Irländer et al., Eur. Phys. J. B 94, 68 (2020).

MA 19.21 Tue 17:30 P2

^{57}Fe Mössbauer spectroscopy on $FePcF_{16}$ and its μ-Oxo dimer in catalysis reaction — •Felix Seewald[1], Florian Puls[2], Hans-Joachim Knölker[2], and Hans-Henning Klauss[1] — [1]Institute of Solid State and Materials Physics, TU Dresden, D-01069, Germany — [2]Department Chemie, Technische Universität Dresden, Bergstraße 66, D-01069 Dresden, Germany

Iron-hexadecafluorophthalocyanine ($FePcF_{16}$) is used as an oxidation catalyst. Understanding its catalysis mechanism is part of current research. The Fe atom is square planar coordinated by four nitrogen atoms. Both $FePcF_{16}$ and its mu-Oxo dimer ($[FePcF_{16}]_2O$) are already identified as steps of the oxidation cycle.

The Mössbauer spectra of $[FePcF_{16}]_2O$ can be described by two sites at room temperature, both exhibiting quadrupole splitting. A temperature dependent reversible transition between both sites can be observed. Below 30 K the onset of a magnetic hyperfine field is observed obtaining a value of $B_{Hyp} = 48.77(12)$ T at 4.2 K.

The $FePcF_{16}$ spectra show one additional third site with a considerable quadrupole splitting and an electric field gradient largest principle component of $V_{zz} = 154(2)\,V/Å^2$. This site stays paramagnetic down to 4.2 K.

First measurements of the frozen reaction solution unveil an additional fourth site in a characteristic Fe(II) charge and high spin (S=2) state. We will discuss the implications of these findings on the catalysis process.

MA 19.22 Tue 17:30 P2

Approaches towards observing toroidal magnetic moments in Dy-based molecular nanomagnets with Inelastic Neutron Scattering techniques. — •Denny Lamon[1], Julius Mutschler[1], Thomas Ruppert[2], Christopher E. Anson[2], Annie K. Powell[2], and Oliver Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Institut für anorganische Chemie, Universität Karlsruhe, KIT, Germany

Single-molecule toroics (SMT) have been a subject of increasing interest both for their fundamental physics properties and for the potential applications in quantum computers or information storage. In fact the associated vortex arrangement of magnetic moments leads to weaker dipolar interactions and to a lack of interaction with a possible external magnetic field. A particular class of these molecules, which incorporate a triangle of exchange coupled magnetic Dy ions, can support a toroidal magnetic moment; in this work a class of Me_2Dy_3 molecules, there Me = Al, Cr, Fe, is investigated. The available experimental data for magnetic susceptibility and magnetization curves are fitted and simulated using full and effective Hamiltonian models in order to extract the model parameters, especially the tilt angles of the anisotropy axes. The inelastic neutron scattering spectra are simulated in order to develop experimental schemes for directly observing toroidal magnetic moments in SMTs.

MA 19.23 Tue 17:30 P2

Synthesis, optical and magnetic properties of Au-Fe3O4 nanohybrids — •Tatiana Smoliarova, Marina Spasova, Ulf Wiedwald, and Michael Farle — Faculty of Physics, University of Duisburg-Essen, Duisburg, 47057, Germany

Gold-magnetite nanohybrids composed of Fe3O4 and Au nanoparticles (NPs) have attracted large attention due to the evident advantages of Au nanoparticles such as unique biocompatibility, facile surface modification, and high catalytic properties. Herein, we report on the facile room-temperature synthesis approach for Au-Fe3O4 nanohybrids preparation and their optical and magnetic properties investigation.

Au-Fe3O4 nanohybrids were synthesized by chemical precipitation with a chemisorption process of Au nanoparticles (NPs) to the Fe3O4 surface using polyvinylpyrrolidone (PVP) coverage. Prepared NPs were studied by transmission electron microscopy (TEM), UV-vis spectroscopy and magnetometry. The obtained results seem to be the promising step for the core-shell Au-Fe3O4 NPs preparation, in the case of Au NPs will be considered as the seeds for the complete Au shell growth.

This work was supported by European Union*s Horizon 2020 research and innovation program under grant agreement No 857502 (MaNaCa).

MA 19.24 Tue 17:30 P2

Chern insulators at finite magnetic fields in twisted bilayer graphene. — •Miguel Sánchez[1], Tobias Stauber[1,2], and José González[3] — [1]ICMM CSIC Madrid — [2]University of Augsburg — [3]IEM CSIC Madrid

We calculate the topological properties (Chern numbers) of the correlated insulator states of magic angle twisted bilayer graphene (TBG) observed at integer number of electrons per Moiré unit cell.

Using the periodic Landau gauge to make manifest the magnetic translation symmetry and the Peierls' substitution, we obtain the Landau levels and Hofstadter butterfly of TBG. Via a self-consistent Hartree-Fock method we study electron correlations and the Chern insulator states at finite magnetic fields in our atomistic tight-binding description. Also, recent discoveries drive our attention to spontaneous translation symmetry breaking at half-integer fillings.

MA 19.25 Tue 17:30 P2

Differential Phase Contrast and Lorentz 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

Differential Phase Contrast (DPC) and Lorentz microscopy are two well-known techniques for analyzing magnetic structures in the transmission electron microscope (TEM). The Lorentz force inside the magnetic domain of a specimen deflects the transmitted electron beam depending on the orientation of the corresponding magnetic field. This deflected beam then results in a different intensity distribution in the recorded image which can be analyzed. In this contribution we present DPC and Lorentz transmission electron microscope (LTEM) images of a specimen consisting of a CoFe membrane with structured holes. These different kinds of holes inside the magnetic material of the specimen yield interesting domain structures. The focus is on the analysis of these magnetic domain structure and the impact of changing external magnetic fields. For this, a hysteresis loop inside the TEM is recorded. Furthermore, the two different techniques are compared giving the possibility to confirm the resulting domain structure.

MA 19.26 Tue 17:30 P2

Kerr microscopy for all-optical helicity-dependent magnetization switching — •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 ever growing demand for data storing capacities requires the development of high bit density data storage devices with fast read and write capabilities. New generation heat assisted magnetic recording devices (HAMR) emerging the market are promising candidates decreasing bit sizes. Simultaneously, the recording media based on nanometer sized FePt grains are suitable for other writing approaches like the all-optical helicity-dependent switching (AOHDS) [1]. We investigate this method for potential future applications of HAMR media. 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. The setup can be implemented in pump-probe experiments to investigate magnetization changes after the deposition of ultrashort laser pulse energies in magnetic thin films. Besides measurements on hard drive media, the microscope can also be used for the observation of skyrions.

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

MA 19.27 Tue 17:30 P2

Magnetic proximity effect in V uncovered by TEM techniques — •Inga Ennen[1], Daniela Ramermann[1], Dominik Graulich[1], Trevor Almeida[2], Stephen McVitie[2], Björn Büker[1], Timo Kuschel[1], and Andreas Hütten[1] — [1]Universität Bielefeld, Dünne Schichten und Physik der Nanostrukturen, Universitätsstr. 25, 33615 Bielefeld, Germany — [2]University of Glasgow, School of Physics and Astronomy, Glasgow G12 8QQ, UK

Thin film structures consisting of magnetic and non-magnetic materials are of great technical interest, due to their special magnetic and electronic characteristics. These characteristics were influenced e.g. by the interface quality and the magnetic proximity effect. Here, the penetration depth of magnetism in non-magnetic films adjacent to ferromagnetic layers is investigated, usually by employing X-ray techniques such as XRMR. In this contribution, we demonstrate the opportunities of modern transmission electron microscopy techniques for the investigation of the magnetic proximity effect in a V/Fe thin film system as a model sample. Here, a combination of magnetic differential phase contrast (DPC) and electron energy loss magnetic chiral dichroism (EMCD) has been employed. The basic idea is that DPC measures the presence of a magnetic induction into V and EMCD shows that there is a magnetic moment present. In this way, a magnetic proximity effect of about 1.5nm in V has been observed, which is in accordance to corresponding measurements with X-rays.

MA 19.28 Tue 17:30 P2

Imaging the coherent spin dynamics of nitrogen vacancies coupled to $CrTe_2$ at room temperature — •Riccardo Silvioli[1], Martin Schalk[1], Karina Houska[1], Dominik Bucher[2], Zdenek Sofer[3], Andreas V. Stier[1], and Jonathan J. Finley[1] — [1]WSI, TUM — [2]Chemie, TUM — [3]UCT Prague

Magnetic resonance imaging of coupled spin-systems is a technique capable of rendering highly accurate descriptions of magnetic fields even at room temperature, and is therefore lying at the heart of various applications in medicine, chemistry and physics. We present coherent wide-field imaging of a 100 x 100 μm sized region of interest implanted with nitrogen vacancy centers (NVs) in diamond coupled to a 50 nm thick flake of the in-plane van der Waals ferromagnet $CrTe_2$. We can quantitatively probe the stray magnetic field of the material with the NVs' electron spin signal. First, we combine the nano-scale sample shapes measured by atomic force microscope with the magnetic resonance imaging data for accurate reconstruction of the sample's magnetization. We then map out the coherent dynamics of the colour centers coupled to the van der Waals ferromagnet using pixel-wise coherent Rabi and Ramsey imaging of the NV sensor layer. We find that the spin coherence of the ensemble is strictly correlated with the variation in the magnetic field generated by the sample. What results is an enhanced detection of the magnetic field where we describe its variation in three dimensions, improving the reconstruction of the magnetization. Finally, we infer the quantum dynamics using a neural network to speed up the convergence of the pixel-wise Hamiltonian fitting.

MA 19.29 Tue 17:30 P2

Ultrafast Lorentz microscopy with magnetic field excitation at microwave frequencies — Jonathan Tilman Weber, Nikita Porwal, •Andreas Wendeln, Michael Winklhofer, and Sascha Schäfer — Carl von Ossietzky Universität, Oldenburg, Deutschland

Recent progress in the development of laser-driven, high brightness photocathodes offers a path to investigate magnetization dynamics with high spatial and temporal resolution, utilizing a Lorentz imaging approach in ultrafast transmission electron microscopy (UTEM) [1]. In particular, non-optical excitation schemes, such as current or field excitation provide pathways for a selective triggering of magnetic dynamics. Extending the available frequencies in such experiments [2], we developed a TEM sample holder based on a two-dimensional microwave cavity, with which we can excite ferromagnetic resonances in magnetic nanostructures. The microwave excitation signals are phase-locked to the nanolocalized photoemission of ultrashort electron pulses from a Schottky field emitter, using high harmonics of the amplified laser system as a master clock for their synthetization [3]. With this advanced excitation and measurement scheme we aim to image ferromagnetic resonance modes with high spatial and temporal resolution and to further establish ultrafast Lorentz microscopy as a powerful tool to characterize magnetization dynamics on the nanoscale.

[1] N. R. da Silva et al. Phys. Rev. X 8, 031052 (2018).
[2] M. Möller et al. Commun Phys 3, 36 (2020).
[3] M.R. Otto et al. Struct. Dyn. 4, 051101 (2017).

MA 19.30 Tue 17:30 P2

Brownian reservoir computing realized using geometrically confined skyrmions — •Klaus Raab[1], Maarten A. Brems[1], Grischa Beneke[1], Takaaki Dohi[1], Jan Rothörl[1], Fabian Kammerbauer[1], Johan H. Mentink[2], and Mathias Kläui[1,3] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Radboud University, Institute for Molecules and Materials, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands — [3]Graduate School of Excellence Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

We demonstrate experimentally [1] a conceptionally new approach for reservoir computing (RC), that leverages the thermally activated diffusive motion of magnetic skyrmions in a confined, triangular geometry. The combination of gated and thermal skyrmion motion of a single skyrmion already suffices to realize all Boolean logic gate operations including the non-linearly separable XOR operation that cannot be realized using a conventional single layer perceptron. An effective potential well created by the confinement allows for a natural, energy efficient reset mechanism enabled by the thermal fluctuations of the skyrmions. We show that the output training costs using linear regression are low and that our ultra-low power operation using current densities orders of magnitude smaller than used in existing spintronic reservoir computing demonstrations. Our concept can be easily extended by linking multiple confined geometries for scalable and low-energy reservoir computing. [1] K. Raab et al. Brownian reservoir computing with geometrically confined skyrmions - arXiv:2203.14720

MA 19.31 Tue 17:30 P2

FD micromagnetic solver for inverse-design magnonics — •Andrey Voronov[1], Qi Wang[1], Dieter Suess[2], Andrii Chumak[1], and Claas Abert[2] — [1]Nanomagnetism and Magnonics, Faculty of Physics, University of Vienna, Austria — [2]Physics of Functional Materials, Faculty of Physics, University of Vienna, Austria

The idea of utilizing a collective excitation of the electron spin system in magnetic solids, so-called spin-waves, for data processing has been developing in recent years. However, the design of complex data-processing units requires elaborate and complicated investigations.

Recently, the concept of inverse-design magnonics, in which any functionality can be specified first and a feedback-based computational algorithm is used to obtain the device design, has been demonstrated numerically [1]. The same algorithm was used to design a magnonic (de-)multiplexer, a nonlinear switch, and a circulator [1].

One of the next challenges for inverse design is the computation of universal Boolean logic gates NAND and NOR. However, such gates require increasing the complexity of the structure used in [1] and the combination of the MuMux3 simulations with the direct binary search algorithm (DBS) is no longer applicable. Here I report on the use of finite difference (FD) micromagnetic solver based on the Pytorch open source machine learning framework for inverse design. The proposed algorithm greatly facilitates the design of the applied devices and is a useful tool especially for spin-wave computing elements.

[1] Wang, Q., et al (2021). Nature Communications, 12(1), 1-9.

MA 19.32 Tue 17:30 P2

Efficiency and Comfort Optimization of Induction Hobs Trough Appropriate Materials Selection — •Lennart Schwan[1,2], Sonja Schöning[1], and Andreas Hütten[2] — [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 nowadays a widely used 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 pot. The ferromagnetic material is heated by induced eddy currents and hysteresis losses Regarding to energy efficiency and comfort, it is desirable to minimize the parasitic losses which do not contribute to the heating of the cooking good and to homogenize the temperature distribution within the cooking container. As a future basis for the development of novel cooking containers, we use FEM simulations to investigate the influence of the material parameters of the ferromagnetic material on the efficiency and temperature distribution. In addition to the simulations, parts of the results are verified by experimental investigations.

MA 19.33 Tue 17:30 P2

Moments and multiplets in moiré materials: A pseudo-fermion functional renormalization group for spin-valley models — •Lasse Gresista, Dominik Kiese, and Simon Trebst — Institute for Theoretical Physics, University of Cologne, Germany

The observation of strongly-correlated states in moiré systems has renewed the conceptual interest in magnetic systems with higher SU(4) spin symmetry, e.g. to describe Mott insulators where the local moments are coupled spin-valley degrees of freedom. In addition to possible geometrical or interaction induced frustration, the enhanced quantum fluctuations in these systems are expected to counteract the formation of magnetic order, making them prime candidates to host exotic quantum spin-valley or spin-orbital liquid ground states. A method that has demonstrated its potential to distinguish between magnetically ordered and disordered states, even in the presence of frustration and in three dimensions, is the pseudo-fermion function renormalization group (pf-FRG). In our work we generalize this method from conventional SU(2) spin models to very general spin-valley Hamiltonians, showing that it can indeed be applied to study the magnetic behavior of moiré materials. We present the quantum phase diagram of $SU(2)^{spin} \otimes U(1)^{valley}$ symmetric spin-valley models relevant for the strong coupling description of trilayer graphene on hexagonal boron nitride (TG/h-BN) and twisted bilayer graphene (TBG).

MA 19.34 Tue 17:30 P2

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 the 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 a 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 then be used to simulate magnetic properties on the next higher hierarchy to the microscopic scale, leading to the so-called multi-scale 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 19.35 Tue 17:30 P2

Multiconfiguretional approch to XAS applied to Co- and Ni- doped magnetite — •Felix Sorgenfrei[1], Johann Schött[1], M'ebarek Alouani[2], Patrik Thunström[1], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Uppsala University, Box-516,Uppsala SE-751 20 Sweden — [2]Université de Strasbourg, IPCMS UMR 7504, 67034 Strasbourg, France

L-edge X-ray absorption spectroscopy (XAS) is an important tool to extract element-specific information about the electronic structure, magnetism and in particular electronic correlation effects. Ab initio calculations typically struggle to reproduce the 2p to 3d excitation, in particular for materials with strong electron correlations and significant core-hole effects. The combination of density functional theory and multiplet ligand field theory is applied to fill this gap. Here, parameters are calculated from first principles and used to construct a single-impurity Anderson model by projecting the local Hamiltonian and hybridization function onto the 3d states. In this talk, this method is applied to NiFe2O4, CoFe2O4 and Fe3O4. We find systematically good agreement with experiment for both XAS and XMCD spectra.

MA 19.36 Tue 17:30 P2

Finite-element dynamic-matrix approach for propagating spin waves: Extension to mono- and multilayers of arbitrary spacing and thickness — •Alexander Hempel[1,2], Lukas Körber[1,2], Andreas Otto[2], Rodolfo Gallardo[3,4], Yves Henry[5], and Attila Kákay[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Germany — [2]Technische Universität Dresden, Germany — [3]UTFSM, Chile — [4]CEDENNA, Chile — [5]IPCMS, France

Over the last few years micromagnetic simulations became an important tool in the field of magnonics. In a recent work Körber et al. [1] presented an efficient method to numerically determine the dispersion and the spatial mode profiles of spin-waves propagating in waveguides with arbitrary cross section, if the equilibrium magnetization is invariant along the propagation direction. In this work their finite-element dynamic-matrix approach is used as a starting point to develop a tool to investigate propagating spin waves in mono- and multilayers. This approach has the advantage, that the linearized equation of motion is solved in just a section of the layers, and has therefore a comparatively low numerical complexity. Nevertheless the dipolar interaction still requires special care and we show how an extension of the Fredkin-Koehler method can be used to handle this problem. As a validation of the method, which is implemented into the open source FEM micromagnetic package TetraX [2], we present a variety of simulation results and compare them with analytics and other numerical approaches.

[1] Körber et al., AIP Advances 11, 095006 (2021). [2] TetraX - DOI: 10.14278/rodare.1418

MA 19.37 Tue 17:30 P2

Predictive Design of Induction Coil Geometries using Neural Networks — •Simon Bekemeier[1], Sven Gehle[1], and Christian Schröder[1,2] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), Bielefeld University of Applied Sciences, Department of Engineering Sciences and Mathematics, Interaktion 1, 33619 Bielefeld, Germany — [2]Faculty of Physics, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

Nowadays, inductive power transfer is an established technology with its most common application in induction hobs. Such appliances usually use planar coils with homogeneous winding distances. With regard to energy efficiency, comfort and electromagnetic compatibility it is desirable to start from an optimal magnetic field distribution and derive the necessary coil geometry from it.

Unknown, highly non-linear functional relations can be modelled using neural networks with relative ease. In this contribution, we use a deep convolutional auto-encoder to predict the relationship between coil geometries and the respective magnetic fields. To achieve this, the current-path and the coil's magnetic field are presented to the neural network in spatially discretized form. By using the current-path as input and the magnetic field as output, the neural net is trained to find coil geometries, which produce a desired magnetic field. In this contribution we present our results of predicted coil designs for magnetic fields, which require coil geometries ranging from simple linear wires to more complex spiral geometries.

MA 19.38 Tue 17:30 P2

First-principles local interactions extracted from non-collinear magnetic states — Miklós Salánki[1], Bendegúz Nyári[1], András Lászlóffy[2], and •László Szunyogh[1] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, Hungary — [2]Wigner Research Centre for Physics, Institute for Solid State Physics and Optics, Hungary

The local Dzyaloshinskii-Moriya interactions (DMI) derived from first principles in non-collinear magnetic configurations in the absence of spin-orbit coupling [1] became recently the subject of an intense discussion [2,3,4]. On the one hand, the local DMI has been explained due to charge and spin currents emerging in non-collinear spin-configurations [1,3], on the other hand, it was shown to be a consequence of fourspin (or higher-order multispin) interactions [2].

As in Ref. [1] we perform calculations of the local interaction parameters for a Cr trimer on Au(111) in terms of the multiple scattering Green's function technique. We use two alternative formalisms that lead to different local parameters. We show that this ambiguity occurs due to longitudinal terms in the corresponding expressions. We find that the formalism based on the structural Green's-funtion matrices provides local interactions being consistent with a spin model including fourspin interactions calculated on the same basis.

[1] R. Cardias *et al.*, arXiv:2003.04680; Sci. Rep. 10, 20339 (2020).
[2] M. dos Santos Dias *et al.*, Phys. Rev. B 103, L140408 (2021).
[3] R. Cardias *et al.*, Phys. Rev. B 105, 026401 (2022).
[4] M. dos Santos Dias *et al.*, Phys. Rev. B 105, 026402 (2022).

MA 19.39 Tue 17:30 P2

Anomalous and spin Hall effect in chiral antiferromagnets Mn_3X (X=Ir, Sn, ...) — •Oliver Busch, Börge Göbel, and Ingrid Mertig — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

Recently, large anomalous Hall effects (AHEs) have been measured in the non-collinear kagome antiferromagnets (AFMs) Mn_3Sn [1] and Mn_3Ge [2] and large spin Hall effects (SHEs) were predicted in such compensated Mn_3X systems [3].

We discuss the intrinsic contributions to both Hall effects of kagome AFMs via tight-binding calculations. We describe a microscopic mechanism for the occurrence of the AHE: within this model, spin-orbit coupling (SOC) is equivalent to an out-of-plane tilting of the magnetic texture [4]. Thus, the AHE can be interpreted as a topological Hall effect generated by the opening angle of the virtually tilted texture.

Besides, we find that the main contribution to the SHE in Mn_3X is a pure spin current originating from the non-collinear magnetic texture and it occurs even without SOC when the AHE is absent [5]. In addition to that, SOC gives rise to the AHE and reduces the SHE effectively which gives rise to spin-polarized currents.

[1] S. Nakatsuji, N. Kiyohara, T. Higo; Nature **527**, 212 (2015)
[2] A. K. Nayak *et al.*; Science Advances **2**, e1501870 (2016)
[3] Y. Zhang *et al.*; New Journal of Physics **20**, 073028 (2018)
[4] O. Busch, B. Göbel, I. Mertig; Phys. Rev. Research **2**, 033112 (2020)
[5] O. Busch, B. Göbel, I. Mertig; Phys. Rev. B **104**, 184423 (2021)

MA 19.40 Tue 17:30 P2

Vertical Pt|$Y_3Fe_5O_{12}$|Pt heterostructures for magnon mediated magnetoresistance measurements — •Philipp Schwenke[1,2], Manuel Müller[1,2], Andreas Haslberger[1,2], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany

Spin currents and their generation (detection) via the (inverse) spin Hall effect in heavy metal (HM)|ferrimagnetic insulator (FMI) heterostructures gain increasing attention in the field of spintronics. In particular, spin current valves in HM|FMI|HM trilayers such as Pt|YIG|Pt heterostructures are of great interest to enable device miniaturization and the implementation of three-dimensional spintronic devices. In this work we optimize the fabrication of these vertical Pt|YIG|Pt heterostructures. We study the interface quality between Pt an YIG by performing angle dependent magnetoresistance measurements on the Pt layers. We observe a good top YIG|Pt interface quality and find an improvement of the bottom Pt|YIG interface by introducing a Ru buffer layer, which reduces the intermixing of Pt and YIG. Furthermore, we observe a finite magnon mediated magnetoresistance and spin Seebeck effect signal in our heterostructures demonstrating the possibility of HM|FMI trilayers as spin current valve devices.

MA 19.41 Tue 17:30 P2

Investigation of Quasipaticle Spin Transport in Superconductors/Ferrimagnet Heterostructures — •Yuhao Sun[1,2], Manuel Müller[1,2], Janine Gückelhorn[1,2], Matthias Grammer[1,2], Hans Huebl[1,2,3], Rudolf Gross[1,2,3], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology, München, Germany

Magnon based spintronics is intensely researched as it enables alternative information processing schemes and additional functionalities compared to charge based counterparts. Recent studies suggest that the interplay of superconductivity and magnetism can enhance spin-related effects, such as the interfacial spin injection efficiency [1]. The present assumption is that magnetic excitation or magnons interact with the quasiparticles of the superconducting phase. To test this conjecture, we investigate magnon injection and transport using the ferrimagnetic insulator $Y_3Fe_5O_{12}$ as magnetic system. In detail, we use a superconducting niobium nitride (NbN) strip as the detector. A heater structure on top of the NbN allows to apply thermal gradient. A spatially separated heavy metal platinum strip acts as the injector of thermal magnon spin-currents. We present temperature dependent data to access the influence of superconducting quasiparticles on our transport signal.

[1] Jeon et al., ACS Nano 14, 15874, (2020).

MA 19.42 Tue 17:30 P2

Nonrelativistic spin currents in altermagnets — •Rodrigo Jaeschke-Ubiergo, Libor Šmejkal, and Jairo Sinova — Institut für Physik, Johannes Gutenberg Universität Mainz, Germany

Altermagnetism has emerged recently as a third basic collinear magnetic phase [1], in addition to ferromagnets and antiferromagnets. Conventional antiferromagnets exhibit two sublattices with opposite magnetic moment related by translation or inversion. In altermagnets the magnetic sublattices are connected by a rotation or a mirror operation. The particular symmetry causes that altermagnets display time-reversal ($\mathcal{T}$) symmetry breaking and spin split band structure even in absence of spin-orbit coupling [2].

In this work, we study the spin conductivity tensor in altermagnets by using spin group theory formalism [1]. We also use Kubo's linear response to calculate the spin conductivity tensor in all the altermagnetic spin point groups models. Additionally, we indentify and sort 200 altermagnetic candidates into spin conductivity tensor classes. We will discuss some spin point groups that allow for a transverse spin current in detail. This is the case of spin splitter current in RuO_2 [3,4], which is a nonrelativistic effect that conserves spin unlike in general magnetic spin Hall effect in noncollinear magnets. Moreover, the spin conductivity tensor is symmetric and $\mathcal{T}$-odd, which makes it different to the conventional spin Hall effect.

[1] Šmejkal, et al. arXiv preprint arXiv:2105.05820, 2021. [2] Šmejkal, et al. Sci.Adv 2020. [3] Gonzalez-Hernandez, et al. PRL 2021. [4] Šmejkal, et al. PRX 2022.

MA 19.43 Tue 17:30 P2

Spin-orbit torques in ferromagnetic heterostructures — •Misbah Yaqoob[1], Fabian Kammerbauer[2], Vitaliy Vasyuchka[1], Gerhard Jakob[2], Mathias Kläui[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany

Spin-orbit torques (SOTs) can be used to electrically control the spin dynamics, while inverse SOTs enable the electrical detection of spin dynamics. Here, based on theoretical predictions [1], we study the spin-to-charge conversion in ferromagnetic materials with high spin-orbit interaction. In particular, we chose the perpendicular magnetic anisotropy (PMA) multilayers CoNi and CoPt. We investigate the spin dynamics and SOTs of corresponding purely metallic ferromagnetic thin film in-plane anisotropy (IPA) / PMA hybrid systems using an inductive technique based on vector network analysis [2].

We observe substantial damping-like SOTs generated in the PMA layers. The SOTs in CoNi/Cu/CoFeB are comparable to those observed in Pt/CoFeB [3] and Pt/NiFe [4] heterostructures using the same technique and similar layer thicknesses.

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[4] A. J. Berger *et al.*, Phys. Rev. B **98**, 024402 (2018).

MA 19.44 Tue 17:30 P2

Current-induced interlayer DMI in synthetic antiferromagnets — •Fabian Kammerbauer[1], Won-Young Choi[1], Freimuth Frank[2], Kyujoon Lee[3], Robert Frömter[1], Yuriy Mokrousov[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Joahnnes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Division of display and semiconductor physics, Korea University, Sejong-ro 2511, Sejong, Republic of Korea

There is rising interest in 3D magnetism and magnetic textures, such as hopfions. Stabilizing 3D magnetic textures is in need of additional interactions favoring the canting of spins in the lateral direction. Layered synthetic antiferromagnets coupled by the symmetric interlayer exchange can additionally display an antisymmetric interlayer exchange, henceforth called interlayer DMI, which exerts such canting. Here, we report the effect of an electrical current on the antisymmetric interlayer DMI by employing anomalous Hall effect measurements with an additional applied in-plane field. In order to quantify the current dependence of the antisymmetric interlayer exchange interaction, an interlayer DMI field is introduced. Using a model of two superimposed cosine functions accounting for current-dependent and static contributions, we demonstrate that the current-dependent interlayer DMI field increases linearly with current and maximal along the direction of current flow. Thus, we demonstrate the possibility to control the interlayer DMI directly by electrical currents.

MA 19.45 Tue 17:30 P2

Spin current transmission in LaSrMnO / NiO / Pt layers — •Evangelos Th. Papaioannou[1], Camillo Ballani[1], Philipp Geier[1], Philip Trempler[1], Christoph Hauser[1], Olena Gomonay[2], and Georg Schmidt[1] — [1]Institute of Physics, Martin-Luther University Halle-Wittenberg, 06120 Halle, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

We investigate the effect of spin pumping and inverse spin-Hall effect (ISHE) in trilayers composed of a ferromagnetic half-metal/ antiferromagnetic oxide/non-magnetic layer in the form of La0.7Sr0.3MnO3/ NiO (x nm) / Pt. The generated spin current is pumped through the antiferromagnetic NiO layer and is detected via ferromagnetic resonance and ISHE measurements at low temperatures down to 10K. We refine two competing mechanisms of spin transport whose contribution to spin transport and supremacy is temperature dependent. The mechanism arising from the direct exchange coupling between FM and AFM dominates below the blocking temperature, while the spin pumping mechanism dominates above the blocking temperature and shows to be more efficient spin current transport through NiO layers.

MA 19.46 Tue 17:30 P2

THz-2D Scanning Spectroscopy — •Finn-Frederik Stiewe, Tobias Kleinke, Tristan Winkel, Ulrike Martens, Jakob Walowski, Christian Denker, and Markus Münzenberg — Institute of Physics, University Greifswald, Germany

THz-spectroscopy offers attractive imaging capabilities for scientific research, especially in life science. Its low photon energies lead to non-destructive interaction with matter In our study, we investigate THz-pulses generated by fs-laser-excitations in CoFeB/Pt heterostructures (STE), based on spin currents together with a LT-GaAs Auston switch as detector. The spatial resolution is tested by applying a 2D scanning technique with motorized stages allowing scanning steps in the sub-micrometer range. By applying an external magnetic field, the spin alignment in the CoFeB layer can be changed and the influence on the THz emission can be studied. For determining the spatial resolution, the STE is directly evaporated on a gold-test pattern separated by a several hundred nanometer thick insulating spacer layer. We observe a THz beam FWHM of 4.86 *0.37 μm at 1 THz by using near-field imaging, which are in the dimension of the laser spot [1]. Our phase sensitive detection allows to image the magnetic alignment of the CoFeB layer. For this purpose, the STE*s are patterned in micrometer sized geometric shapes on a glass substrate and scanned by our 2D scanning technique. Due to its simplicity, our technical approach offers a large potential for wide-ranging applications. [1] F.-F. Stiewe et al., Appl. Phys. Lett. 120, 32406 (2022).

Funding by: MetaZIK PlasMark-T (FKZ:03Z22C511), BMBF

MA 19.47 Tue 17:30 P2

Spatially Resolved Terahertz Spectroscopy using Spintronic-Terahertz-Emitter — •Bruno Rosinus Serrano[1,2], Alex Chekhov[1,2], Yannic Behovits[1,2], and Tobias Kampfrath[1,2] — [1]Freie Universität Berlin — [2]Fritz-Haber-Institut Berlin

New efficient laser-driven sources provide high THz fields suitable for excitation of ultrafast spin dynamics in various materials. These intense THz pulses are often characterized with a use of infrared and THz cameras also known as focal plane arrays (FPA). Since the FPA output strongly depends on its spectral sensitivity, it is often important to know the transfer function of a given FPA in the corresponding THz range. Here, we develop a table-top technique, which allows one to separate and spatially resolve spectral contributions to the FPA image in the THz range. Our results indicate that the FPA sensitivity can be quite resonant at different frequencies.

MA 19.48 Tue 17:30 P2

Identification and characterization of plastics using THz-spectroscopy — •Tobias Kleinke, Finn-Frederik Lietzow, Ulrike Martens, Jakob Walowski, and Markus Münzenberg — Institute of Physics, University Greifswald, Germany

THz-spectroscopy is an attractive tool for scientific research, especially in life science, offering non-destructive interaction with matter due to its low photon energies [1]. Current research investigates the impact of plastic nanoparticles on cell tissue in several aspects, because those particles are highly abundant in the environment and also enter the human body potentially causing harmful interactions [2].

THz spectroscopy offers the opportunity to discover and study the influence of microplastics in living human cells. Our project aims to identify and characterize different types of plastics in the human body or even in cells. Therefore it is necessary to set up a database with THz-spectra of the most abundant polymers. We analyse transmission spectra of several plastics with a commercial THz spectrometer (bandwidth from 0.1 to 6 THz) and identified specific absorption peaks for the individual studied materials. Furthermore, by determining the refractive index and the absorption coefficient, specific polymers can be characterized and identified.

[1] W. Shi et al., Journal of Biophysics, Vol. 14, 2021
[2] A. Ragusa et al., Environment International, Vol. 146, 2021

MA 19.49 Tue 17:30 P2

Spin-Hall-Angle measurements on magnetic heterostructures with bismuth alloys using THz-spectroscopy — •Tristan Winkel[1], Finn-Frederik Stiewe[1], Jakob Walowski[1], Christian Denker[2], and Markus Münzenberg[1] — [1]Institute of Physics, University Greifswald, Germany — [2]EMCC DR. RASEK, Ebermannstadt, Deutschland

Spin Hall angle measurements are important for spin device design. THz spectroscopy provides effective means to measure spin Hall angles. In our study, we investigate THz pulses generated by fs laser excitations in magnetic heterostructures based on spin currents, together with an LT-GaAs Auston switch as a detector. The magnetic heterostructures consist of a CoFeB layer and a heavy metal layer such as bismuth alloys [1]. From the THz measurement, we can extrapolate the spin Hall angle of the heavy metal. The data is then used to build optimized spin Hall nano-oscillators for the fabrication of a neuromorphic computer chip [2]. Our technical approach offers great potential for wide-ranging applications due to its simplicity.

[1] Caiyun Hong et al., Advanced Electronic Materials. 10.1002/aelm.201700632 (2018)
[2] M. Zahedinejad et al., Appl. Phys. Lett. 112, 132404 (2018)

MA 19.50 Tue 17:30 P2

Formation and decay dynamics of the perpendicular standing spin-wave (PSSW) mode following the ultrafast demagnetization of an ultrathin permalloy film — •Anulekha De[1], Akira Lentfart[1], Laura Scheuer[1], Benjamin Stadtmüller[1,2], Philipp Pirro[1], Georg von Freymann[1,3], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM

One of the most thoroughly explored spin-wave modes in ferromagnetic films is the perpendicular standing spin wave (PSSW) mode, the coherent excitation of which require nonuniform excitation or pinning of the magnetization. By tuning the film thickness, it is possible to shift this mode to the sub-THz regime due to the increased exchange contribution quantized over the thickness. Here, we demonstrate the formation of the first PSSW mode on the ps timescale following the optically induced ultrafast demagnetization of the thin Py film using fs-light pulses in an all-optical, time-resolved magneto-optical Kerr effect (tr-MOKE) technique. For the excitation of coherent spin waves using ultrashort laser pulses, the magnetization of the samples was canted in OOP direction with an external field. The observed time-dependent behavior of the first PSSW mode gives an insight into the role of spin waves during the ultrafast demagnetization and remagnetization process. This research was supported by the DFG through No. TRR 173-268565370 (B11).

MA 19.51 Tue 17:30 P2

Characterizing electro-optic terahertz analyzers using a polarization-tunable spintronic terahertz emitter — •Genaro Bierhance[1,2], Oliver Gueckstock[1,2], and Tobias Kampfrath[1,2] — [1]Department of Physical Chemistry, Fritz Haber Institute of the Max Planck Society, 14195 Berlin, Germany — [2]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany

One goal of current spintronics research is to push the speed of spin torques, transport and their detection to terahertz (THz) frequencies. Here, THz spectroscopy is a powerful tool that provides immediate access to the femtosecond time scales of spin dynamics. The toolbox of THz spectroscopy was recently extended by spintronic emitters (STEs), which provide efficient, spectrally broad and gapless emission in the THz frequency range.

Here, we show that the emitted THz field has a linear polarization with a high intensity purity. The polarization axis can easily be set by an external magnetic field. Subsequently, we use this property to quantify the capability of the electro-optic crystals ZnTe and GaP as THz polarization analyzers in the context of electro-optic THz detection. We find excellent performance with frequency-resolved intensity extinction ratios up to 40,000:1.

MA 19.52 Tue 17:30 P2

Orbitronic influences on spintronic THz emitters — •Julien Schäfer, Laura Scheuer, Philipp Pirro, and Burkard Hillebrands — TU Kaiserslautern, Kaiserslautern, Deutschland

Magnetic / non-magnetic thin film bilayers were recently introduced as novel sources of THz radiation: A fs laser pulse generates a spin current in the ferromagnetic layer which diffuses into the non-magnetic layer. Usually, the non-magnetic layer is chosen to exhibit a high spin-orbit coupling in order to efficiently transform the spin current into a charge current via the inverse spin-Hall effect. The accelerated electrons of the transient charge current then emit a broadband radiation in the THz regime.
The orbital Hall effect is reported to be remarkably long-ranged in ferromagnets and to generate considerate spin-orbit torques on CuO_X/Pt interfaces [1]. Therefore, we investigated Co/Pt-emitters in various combinations with CuO_X and Al_2O_3 as an insulator barrier to extract the influence of a potential inverse orbital Hall effect on the THz emission. The exploitation of the inverse orbital Hall effect opens new perspectives in terms of material choices for the next generation of spintronic THz emitters.

[1]: D. Go *et al.*: *Long-Range Orbital Transport in Ferromagnets*, arXiv:2106.07928 [cond-mat.mes-hall] (2022)

MA 19.53 Tue 17:30 P2

Enhancement of THz emission from Fe/L1$_0$-FePt/Pt spintronic emitters — •Laura Scheuer[1], Moritz Ruhwedel[1], Dominik Sokoluk[3], Garik Torosyan[4], Marco Rahm[3], Burkard Hillebrands[1], Thomas Kehagias[2], René Beigang[1], and Evangelos Papaioannou[5] — [1]Department of Physics and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany — [2]Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece — [3]Fachbereich Elektro-Informationstechnik and Landesforschungszentrum OPTIMAS, University of Kaiserslautern, Kaiserslautern, Germany — [4]Photonic Center Kaiserslautern, Kaiserslautern, Germany — [5]Institute for Physics, Martin-Luther University Halle Wittenberg, Halle, Germany

The development of thin film multilayers composed of a ferromagnetic metal (FM) layer and a non-magnetic metal (NM) layer as sources for THz emission opened a new direction in physics.
In this presentation we concentrate on the impact of the FM/NM interface on the THz emission. We intentionally modify the Fe/Pt interface by manipulating the Pt growth temperature to achieve the formation of an ordered L1$_0$-FePt alloy interlayer. Subsequently, we find a Fe/L1$_0$-FePt (2nm)/Pt configuration to be significantly superior to a Fe/Pt bilayer structure, regarding THz emission amplitude and bandwidth. Both can be controlled by the extent of alloying on either side of the interface [1].

[1] L. Scheuer *et al.*: *THz emission from Fe/Pt spintronic emitters with L1$_0$-FePt alloyed interface, iScience*, Volume 25, Issue 5, 2022

MA 19.54 Tue 17:30 P2

Spectral characteristics of microstructured spintronic THz emitters — •Rieke von Seggern[1], Christopher Rathje[1], Leon Gräper[1], Jana Kredl[2], Jakob Walowski[2], Markus Münzenberg[2], and Sascha Schäfer[1] — [1]Institute of Physics, University of Oldenburg, Germany — [2]Institute of Physics, University of Greifswald, Germany

The introduction of spintronic terahertz emitters (STE) opened up a new class of terahertz (THz) sources with useful properties for spectroscopy applications, such as an ultrabroad and gapless emission spectrum and high THz peak field strengths [1].

Here, a resonator-grafted STE bilayer (CoFeB/Pt) is illuminated by a focused optical excitation pulse (780-nm central wavelength, 70-fs pulse duration, 16-um FWHM spot size) to generate a micrometer-scale broadband THz source. The radiated THz field coupled to the adjacent resonator is recorded via electro-optic sampling, dependent on the excitation location. Remarkably, the emitted THz signal changes drastically due to the coupling of the local dipole to the microresonators [2]. The spectral influence of different resonator geometries is experimentally demonstrated, and the underlying physical mechanisms are discussed based on detailed numerical simulations of the phenomenon. Special emphasis is placed on the interplay between intrinsic resonator characteristics and angular THz emission distributions.

[1] Seifert et al., Nat. Photonics 10, 483 (2016)

[2] Rathje, von Seggern et al., manuscript in preparation

MA 19.55 Tue 17:30 P2

Domain structure of few-layer Fe_3GeTe_2 microflakes — •Honey Boban[1], Keda Jin[2], Tobias Wichmann[2], Anna Mandziak[3], Ewa Madej[3], Jose Martinez Castro[2], Vitaliy Feyer[4], Iulia Cojocariu[4], Daniel Baranowski[4], Felix Lupke[2], Claus Michael Schneider[1], and Lukasz Plucinski[1] — [1]PGI-6, Forschungszentrum Juelich — [2]PGI-3, Forschungszentrum Juelich — [3]SOLARIS Centre, Krakow — [4]Elettra Synchrotron, Trieste

Fe_3GeTe_2 is a ferromagnetic 2D metal with a bulk transition temperature of 220K[1]. Monolayer FGT is inversion asymmetric, whereas in the bulk inversion symmetry is recovered because of the AB stacking. FGT exhibits stripe domain patterns with an average width of 140 nm at 110K[1]. Within each layer a combination of inversion asymmetry with ferromagnetism gives rise not only to a finite spin polarization but also to energy shifts of spectral features between K and K' momenta[2].

To study the spin polarized bands in FGT, we shall probe a single terrace with domain larger than the photon beamspot. We exfoliated FGT flakes of 4-5 monolayer thickness on graphite/Au/SiO_2 in a glovebox and encapsulated them with graphene, since thin FGT flakes degrade rapidly in ambient conditions[3]. Dichroic PEEM measurements on these flakes showed single domains of sizes up to 4 x 3 μm, when cooled down to <100K. The thin flakes with 4 x 3 μm single domain can be used to demonstrate the predicted asymmetries at the K and K' points.

[1] Nano Lett. **18**, 5974(2018), [2] Nature Physics **10**, 387(2014), [3] npj 2D Materials and Applications **4**, 33(2020)

MA 19.56 Tue 17:30 P2

Exchange interactions in monolayers of the $MnBi_2Te_4$ family — •Donya Mazhjoo, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Due to their novel properties, two-dimensional magnetic materials are highly desirable for spintronic applications. An interesting material is $MnBi_2Te_4$ [1]. Of substantial interest is the relating of the intrinsically topological properties of $MnBi_2Te_4$ and the magnetic interactions and the impact of the alteration of their chemical constitution. The question can be resolved by density functional theory (DFT), which enables the calculation of the magnetic interaction directly from the electronic structure.
By using the full-potential linearized augmented planewave method (FLAPW) as implemented in the Fleur-code [2], we analyzed the exchange interaction in septuple layers of $MnBi_2Te_4$ type. Mapping our results on the extended Heisenberg model, we disentangle different exchange interactions, spin-orbit coupling effects like the magnetocrystalline anisotropy, and higher-order interactions [3]. Also, applying an external electric field breaks the inversion symmetry and allows for a strong DMI that may lead to the realization of metastable topological magnetic structures [4].
[1] M. Otrokov et al., Nature **576**, 416 (2019).
[2] https://www.flapw.de
[3] M. Hoffmann et al., Phys. Rev. B **101**, 024418 (2020).
[4] D. Mazhjoo et al., Proc. SPIE **11470**, 114702S (2020).

MA 19.57 Tue 17:30 P2

Investigation of the surface structure of $Y_3Fe_5O_{12}$ thin films by X-ray photoelectron spectroscopy and diffraction (XPS and XPD) — •Thomas Ruf[1], Philip Trempler[2], Georg Schmidt[2], and Reinhard Denecke[1] — [1]Wilhelm-Ostwald-Institut, Universität Leipzig — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

$Y_3Fe_5O_{12}$ (YIG) is a ferrimagnetic and insulating material with low ferromagnetic resonance (FMR) linewidth and damping constant. High surface quality and complete epitaxial growth are important for YIG thin films. High-quality YIG thin films are good candidates for integrated magnonics and spin injection in YIG/metal bilayers.

XPD measurements for assignment of the surface structure of pulsed laser deposited, high quality and pseudomorphic YIG(100) on $Gd_3Ga_5O_{12}$(100) and YIG(111) on $Gd_3Ga_5O_{12}$(111) 50 nm thin films were conducted. XPS angular intensity anisotropies for high kinetic energy lines Y 3d (E_{kin} = 1329 eV), Fe 3p (E_{kin} = 1430 eV) and O 1s (E_{kin} = 957 eV) of the thin films can be interpreted in the forward focusing regime as a bulk-like (SG Ia3d) surface structure. Simplifying the interpretation to forward focusing allows for interpretation as a real space scan. The normalized intensity for Y 3d and Fe 3p lies in the range of 0.85 to 1.2 and approx. 0.9 to 1.1 for O 1s. This confirms epitaxial coherence reaching to the film surface, as XPD effects are restricted to few atomic layers. The measured XPS quantification ratios of 1.1 and 1.2 for [Y]/[Fe], compared to nominally 0.6, can only be partly explained by those XPS angular intensity anisotropies.

MA 19.58 Tue 17:30 P2

Ti , V, Ta, Nb as a boron sink in crystalline CoFeB/ MgO/ CoFeB Magnetic Tunnel Junctions — •Tobias Peters, Laila Bondzio, Inga Ennen, and Günter Reiss — Center for Spinelectronic Materials and Devices, University of Bielefeld, Germany

We investigated the tunnel magnetoresistance (TMR) in CoFeB/MgO/ CoFeB Magnetic Tunnel Junctions (MTJs) and studied the use of Ti, V, Ta and Nb as a boron getter during thermal annealing. Exchange bias MTJs were deposited by sputtering deposition. The basic TMR stack was modified by inserting an additional ultrathin layer into the CoFeB bottom electrode and changing the capping layer with the stated materials. TMR measurements have been performed for samples post-annealed at temperatures from 270°C to 420°C for 1h. The boron diffusion was observed via Electron Energy Loss Spectroscopy and Transmission Electron Microscopy. Nb-samples show the highest TMR for post-annealing temperatures smaller then 360°C. For higher temperatures we found even higher TMR for a Ta-sample. However, the insertion of Ta in the CoFeB electrode leads to a severe loss of pinning.

MA 19.59 Tue 17:30 P2

Magnetization dynamics in hybrid ferromagnetic / antiferromagnetic systems — •Hassan Al-Hamdo[1], Yaryna Lytvynenko[2], Gutenberg Kendzo[1], Misbah Yaqoob[1], Moritz Ruhwedel[1], Philipp Pirro[1], Olena Gomonay[2], Vitaliy I. Vasyuchka[1], Mathias Kläui[2], Martin Jourdan[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany

While typical antiferromagnetic magnons are in the THz range at zero external magnetic field, ferromagnetic magnons are gapless. A ferromagnet/antiferromagnet bilayer is thus expected to host hybrid spin excitations. We study the magnetization dynamics of $Mn_2Au/Ni_{80}Fe_{20}$ thin film bilayers. This system allows us to control the Mn_2Au Néel vector orientation with moderate external magnetic fields [1]. Mn_2Au furthermore shows strong spin-orbit torque efficiency [2] making this system intriguing for all-electrical control of magnetization direction. By varying the thickness of $Ni_{80}Fe_{20}$, we investigated the effect of the $Mn_2Au/Ni_{80}Fe_{20}$ interface on $Ni_{80}Fe_{20}$ spin dynamics. Broadband ferromagnetic resonance and Brillion light scattering experiments reveal that interfacial exchange coupling causes an increase in the resonance frequency of $Ni_{80}Fe_{20}$.
Reference(s): [1] Bommanaboyena et al., Nature Communications **12**, 6539 (2021) [2] Bodnar et al., Nature Communications **9**, 348 (2018)

MA 19.60 Tue 17:30 P2

Imaging the magnetic structure of antiferromagnetic PtMn — •Beatrice Bednarz, Christin Schmitt, Hendrik Meer, Adithya Rajan, Mathias Kläui, and Gerhard Jakob — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Antiferromagnetic materials (AFM) are gaining increasing interest in the recent years because of their high potential for new spintronic devices with very high bit packing densities and ultrafast dynamics. [1] PtMn is widely used, especially to pin ferromagnetic layers in magnetic devices. [2] $Pt_{50}Mn_{50}$ has a CuAu-I type structure with a high bulk Néel temperature of 975 K. [3] THz spin dynamics [4] and periodic chiral structures [5] have been predicted in PtMn. However, to use it as the active layer of spintronic devices, the first crucial step is to read out its magnetic state. This was achieved now by imaging the domains with x-ray magnetic linear dichroism (XMLD). Additionally, the domain size was determined from a Fourier transform of the XMLD images for 40 nm PtMn grown on MgO (001) and capped with 1.6 nm Al. It shows a distinct ring, corresponding to an average domain periodicity of approximately 650 nm.

[1] V. Baltz et al., Rev. Mod. Phys. 90, 015005 (2018). [2] G.W. Anderson et al., J. Appl. Phys. 87, 5726 (2000). [3] L. Pál et al., J. Appl. Phys. 39, 538 (1968). [4] K. Kang et al., ArXiv:2112.13954 [Cond-Mat] (2021). [5] Md.R.K. Akanda et al., Phys. Rev. B 102, 224414 (2020).

MA 19.61 Tue 17:30 P2

Ultrafast Magnetization Dynamics in spin Hall nano-oscillators layer-stacks with different heavy metals — •Tahereh Sadat Parvini, Jakob Walowski, and Markus Muenzenberg — Institut für Physik, Universität Greifswald, Greifswald, Germany

We employed an all-optical time-resolved magneto-optical Kerr effect (TRMOKE) microscope for an unambiguous determination of oscillation frequency and Gilbert damping of spin Hall nano-oscillators. The structures of the stacks are $WTa(5)/Py(7)/Pt(2)/HfO_X$, $W(5)/Py(7)/Pt(2)/HfO_X$, $Py(7)/PtCu(5)/HfO_X$, and $Py(7)/PtCr(5)/HfO_X$ (thicknesses are in nm). The oscillation frequency and effective damping parameters are investigated as a function of the intensity and direction of the external magnetic field, the intensity of the pump, and cap layer thicknesses. Our results show stacks with PtCr and PtCu cap layers have smaller Gilbert damping than stacks with Pt cap layers. This study paves the way for developing ultrafast spintronic devices for data storage and information processing.

MA 19.62 Tue 17:30 P2

Direct imaging of current-induced antiferromagnetic switching in NiO revealing a pure thermomagnetoelastic switching mechanism — •Hendrik Meer[1], Felix Schreiber[1], Christin Schmitt[1], Rafael Ramos[2,3], Eiji Saitoh[2,4], Olena Gomonay[1], Jairo Sinova[1], Lorenzo Baldrati[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Mainz, Germany — [2]CIQUS, Departamento de Quimica-Fisica, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [3]WPI-

Advanced Institute for Materials Research, Tohoku University, Sendai, Japan — [4]Department of Applied Physics, The University of Tokyo, Tokyo, Japan

Antiferromagnetic spintronics is considered as a disruptive approach, enabling scalable ultrafast and efficient spintronic devices. We observe current-induced magnetic switching of insulating antiferromagnet/heavy metal bilayers. Previously, different reorientations of the Néel order for the same current direction were reported for different device geometries and different switching mechanisms were proposed. Here, we combine concurrent electrical readout and optical imaging of the switching of antiferromagnetic domains with simulations of the current-induced temperature and strain gradients. By comparing the switching in specially engineered NiO/Pt device and pulsing geometries, we can rule out dominating spin-orbit torque based mechanisms and identify a thermomagnetoelastic mechanism to switch the antiferromagnetic domains, reconciling previous reports.

MA 19.63 Tue 17:30 P2

Spin Hall magnetoresistance effect in orthoferrites/Pt heterostructures. — S. Becker[1], •E.F. Galindez-Ruales[1], A. Ross[1], E. Pomjakushina[2], F. Schreiber[1], R. Lebrun[1,3], G. Jakob[1], O. Gomonay[1], and M. Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany. — [2]Laboratory for Multiscale Materials Experiments, PSI, 5232, Villigen PSI, Switzerland — [3]Unité Mixte de Physique CNRS-Thales, Palaiseau, France

Although there are advantages of antiferromagnetic systems [1], there are some limitations in the length of the spin transmission distance that only recently have been tackled using orthoferrites [2]. $TmFeO_3$ (TFO), a rare earth orthoferrite, possesses both collinear antiferromagnetic ordering and a net canted ferromagnetic moment. That is due to the bulk Dzyaloshinskii-Moriya interaction (DMI), which leads to a canting of the four magnetic iron sublattices [3]. Spin Hall magnetoresistance (SMR) is used to investigate the magnetic properties of a bulk sample [4] . We can identify the onset of the spin reorientation transition (SRT) as well as the spin-flop field, which changes approximately linearly with temperature around the SRT. We observe differences between the different devices likely stemming from the symmetry breaking at the TFO/Pt interface due to interfacial DMI.

[1] Lebrun, R., et al. Nat. Commun 11, 6332 (2020). [2] S. Das, et. al. ArXiv:2112.05947 [cond-mat.str-el] [3] S. Becker, et.al. Phys. Rev. B103, 024423 (2021). [4] R. Lebrun, et. al. Commun. Phys. 2, 50 (2019).

MA 19.64 Tue 17:30 P2

Structure and magnetism of hematite nanodiscs — •Maryna Spasova and Michael Farle — Faculty of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, Germany

Hexagonal shaped, single crystal hematite nanodiscs with thickness of 20 nm and different lateral sizes from 110 nm up to 250 nm were synthesized by an alcohol-thermal reaction. High Resolution Transmission Electron Microscopy reveals a very high crystallinity with (0001) basal planes and (101-2) side surfaces. The temperature of the Morin transition (MT) decreases for smaller diameters of the nanodiscs. The magnetization above the MT, however, does not depend on the particle size. It is close to the bulk value (M = 0.3 Am2/kg) whereas the coercivity decreases with increasing diameter from 55 kA/m (110 nm) to 37 kA/m (250 nm). Below the MT the nanodiscs are ferromagnetic r due to uncompensated surface magnetic moments which are perpendicular to the (0001) crystal plane. The magnetization measured at 10K is proportional to the surface area of the sample. The coercivity at 10 K increases with increasing particle diameter, i.e. 50 kA/m for 110 nm up to 550 kA/m for 250 nm. A very high irreversibility field of 3000 kA/m indicates a high magnetic anisotropy of the sample.