Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

(Lecture halls H37, H43, H47, and H48; Poster P2 and P4)

Invited Talks

MA 10.1	Mon	15:00–15:30	H47	**Magnetic vortices: into the third dimension** — •Sebastian Gliga
MA 12.1	Tue	9:30–10:00	H37	**Topological spin structures at surfaces** — •Stefan Heinze
MA 14.1	Tue	9:30–10:00	H47	**Overriding universality of ferromagnetic phase transitions through nano-scale materials design** — •Andreas Berger
MA 17.1	Tue	15:00–15:30	H43	**Ultimately fast, small and energy-efficient magnetism: fundamentals and prospects** — •Johan Mentink
MA 17.2	Tue	15:30–16:00	H43	**From spintronics at limiting temporal and spatial scales in antiferromagnets to an emerging altermagnetic phase** — •Tomas Jungwirth
MA 17.3	Tue	16:00–16:30	H43	**An electronic structure viewpoint on candidate van der Waals ferromagnets** — •Phil King, Matt Watson, Brendan Edwards, Akhil Rajan, Jiagui Feng, Deep Biswas, Monica Ciomaga Hatnean, Amelia Hall, Geetha Balakrishnan, Giovani Vinai, David Burn, Thorsten Hesjedal, Gerrit van der Laan, Oliver Dowinton, Saeed Bahramy
MA 17.4	Tue	16:30–17:00	H43	**Nano-scale skyrmions and atomic-scale spin textures studied with STM** — •Kirsten von Bergmann
MA 20.1	Wed	9:30–10:00	H37	**Recent developments in X-ray three-dimensional magnetic imaging** — •Valerio Scagnoli
MA 20.2	Wed	10:00–10:30	H37	**Magnetic depth profiling with x-ray resonant magnetic reflectivity (XRMR)** — •Timo Kuschel
MA 20.3	Wed	10:30–11:00	H37	**Magnetic Bragg Ptychography Studies of Spin Caloritronic** — •Dina Carbone, Peng Li, Stephan Geprägs, Rudolf Gross, Paul Evans, Virginie Chamard, Dan Mannix
MA 20.4	Wed	11:15–11:45	H37	**Imaging the 3D magnetic texture of skyrmion tubes and approaches towards determining their Hall signature** — •B. Rellinghaus, S. Schneider, D. Wolf, U.K. Rössler, M. Schmidt, A. Kovács, R.E. Dunin-Borkowski, D. Pohl, A. Thomas, D. Krieger, B. Büchner, A. Lubk
MA 20.5	Wed	11:45–12:15	H37	**Determination of spin chirality and helicity angle by circular dichroism in soft x-ray absorption and resonant elastic scattering** — •Gerrit van der Laan
MA 20.6	Wed	12:15–12:45	H37	**Identification of complex spin-textures by novel Hall effects** — •Juba Bouaziz, Hiroshi Ishida, Samir Lounis, Stefan Blügel
MA 31.1	Thu	15:00–15:30	H37	**Neutron scattering on magnetic topological materials: From topological magnon insulators to emergent many-body effects** — •Yixi Su

Invited Talks of the joint Symposium Frontiers of Orbital Physics: Statics, Dynamics, and Transport of Orbital Angular Momentum (SYOP)

See SYOP for the full program of the symposium.

SYOP 1.1	Mon	9:30–10:00	H1	**Orbital degeneracy in transition metal compounds: Jahn-Teller effect, spin-orbit coupling and quantum effects** — •Daniel Khomskii

SYOP 1.2	Mon	10:00–10:30	H1	**Orbital magnetism out of equilibrium: driving orbital motion with fluctuations, fields and currents** — •Yuriy Mokrousov
SYOP 1.3	Mon	10:30–11:00	H1	**Orbitronics: new torques and magnetoresistance effects** — •Mathias Kläui
SYOP 1.4	Mon	11:15–11:45	H1	**Orbital and total angular momenta dichroism of the THz vortex beams at the antiferromagnetic resonances** — •Andrei Sirenko
SYOP 1.5	Mon	11:45–12:15	H1	**Observation of the orbital Hall effect in a light metal Ti** — •Gyung-Min Choi

Invited Talks of the joint Symposium SKM Dissertation Prize 2022 (SYSD)

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	10:15–10:45	H2	**Charge localisation in halide perovskites from bulk to nano for efficient optoelectronic applications** — •Sascha Feldmann
SYSD 1.2	Mon	10:45–11:15	H2	**Nonequilibrium Transport and Dynamics in Conventional and Topological Superconducting Junctions** — •Raffael L. Klees
SYSD 1.3	Mon	11:15–11:45	H2	**Probing magnetostatic and magnetotransport properties of the antiferromagnetic iron oxide hematite** — •Andrew Ross
SYSD 1.4	Mon	11:45–12:15	H2	**Quantum dot optomechanics with surface acoustic waves** — •Matthias Weiss

Invited Talks of the joint Symposium United Kingdom as Guest of Honor (SYUK)

See SYUK for the full program of the symposium.

SYUK 1.1	Wed	9:30–10:00	H2	**Structure and Dynamics of Interfacial Water** — •Angelos Michaelides
SYUK 1.2	Wed	10:00–10:30	H2	**A molecular view of the water interface** — •Mischa Bonn
SYUK 1.3	Wed	10:30–11:00	H2	**Motile cilia waves: creating and responding to flow** — •Pietro Cicuta
SYUK 1.4	Wed	11:00–11:30	H2	**Cilia and flagella: Building blocks of life and a physicist's playground** — •Oliver Bäumchen
SYUK 1.5	Wed	11:45–12:15	H2	**Computational modelling of the physics of rare earth - transition metal permanent magnets from $SmCo_5$ to $Nd_2Fe_{14}B$** — •Julie Staunton
SYUK 2.1	Wed	15:00–15:30	H2	**Hysteresis Design of Magnetic Materials for Efficient Energy Conversion** — •Oliver Gutfleisch
SYUK 2.2	Wed	15:30–16:00	H2	**Non-equilibrium dynamics of many-body quantum systems versus quantum technologies** — •Irene D'Amico
SYUK 2.3	Wed	16:00–16:30	H2	**Quantum computing with trapped ions** — •Ferdinand Schmidt-Kaler
SYUK 2.4	Wed	16:45–17:15	H2	**Breaking the millikelvin barrier in cooling nanoelectronic devices** — •Richard Haley
SYUK 2.5	Wed	17:15–17:45	H2	**Superconducting Quantum Interference Devices for applications at mK temperatures** — •Sebastian Kempf

Sessions

MA 1.1–1.1	Sun	16:00–17:30	H1	**Tutorial: Careers in Science (joint session MA/TUT)**
MA 2.1–2.4	Mon	9:30–10:30	H37	**Magnetic Imaging Techniques**
MA 3.1–3.3	Mon	9:30–10:15	H43	**Spin-Dependent Phenomena in 2D**
MA 4.1–4.4	Mon	9:30–10:30	H47	**Disordered Magnetic Materials**
MA 5.1–5.4	Mon	9:30–10:30	H48	**Magnetic Instrumentation and Characterization**
MA 6.1–6.4	Mon	11:00–12:00	H37	**Complex Magnetic Oxides**
MA 7.1–7.4	Mon	11:00–12:00	H43	**Magnetic Relaxation and Gilbert Damping**
MA 8.1–8.12	Mon	15:00–18:00	H37	**Ultrafast Magnetization Effects 1**
MA 9.1–9.4	Mon	15:00–17:00	H43	**INNOMAG e.V. Prizes 2022 (Diplom-/Master and Ph.D. Thesis)**
MA 10.1–10.6	Mon	15:00–16:45	H47	**Non-Skyrmionic Magnetic Textures**
MA 11.1–11.8	Mon	15:00–17:00	H48	**Computational Magnetism 1**
MA 12.1–12.12	Tue	9:30–12:45	H37	**Skyrmions 1 (joint session MA/KFM)**
MA 13.1–13.12	Tue	9:30–12:30	H43	**Magnonics 1**
MA 14.1–14.9	Tue	9:30–12:00	H47	**Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions**

MA 15.1–15.8	Tue	9:30–11:30	H48	**Computational Magnetism 2**
MA 16.1–16.11	Tue	15:00–17:45	H37	**Frustrated Magnets**
MA 17.1–17.4	Tue	15:00–17:00	H43	**PhD Focus Session: The Hitchhiker's Guide to Spin Phenomena at the Space and Time Limit**
MA 18.1–18.9	Tue	15:00–17:15	H47	**Spintronics**
MA 19.1–19.64	Tue	17:30–20:00	P2	**Poster 1**
MA 20.1–20.7	Wed	9:30–13:00	H37	**Focus Session: Revealing Multidimensional Spin Textures and their Dynamics via X-rays and Electrons**
MA 21.1–21.11	Wed	9:30–12:15	H43	**Terahertz Spintronics**
MA 22.1–22.9	Wed	9:30–11:45	H47	**Thin Films: Magnetic Coupling Phenomena / Exchange Bias / Magnetic Anisotropy**
MA 23.1–23.5	Wed	9:30–10:45	H48	**Magnetic Domain Walls**
MA 24.1–24.12	Wed	15:00–18:00	H37	**Spin Transport and Orbitronics, Spin-Hall Effects**
MA 25.1–25.8	Wed	15:00–17:00	H43	**Ultrafast Magnetization Effects 2**
MA 26.1–26.4	Wed	15:00–16:00	H48	**Molecular Magnetism**
MA 27.1–27.13	Thu	9:30–12:45	H37	**Skyrmions 2 (joint session MA/KFM)**
MA 28.1–28.13	Thu	9:30–12:45	H43	**Magnonics 2**
MA 29.1–29.9	Thu	9:30–11:45	H47	**Caloric Effects in Magnetic Materials**
MA 30.1–30.8	Thu	9:30–11:30	H48	**Surface Magnetism**
MA 31.1–31.10	Thu	15:00–17:45	H37	**Topological Insulators (joint session MA/KFM)**
MA 32.1–32.8	Thu	15:00–17:00	H43	**Bulk Materials: Soft and Hard Permanent Magnets**
MA 33.1–33.7	Thu	15:00–16:45	H47	**Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)**
MA 34.1–34.7	Thu	15:00–16:45	H48	**Functional Antiferromagnetism**
MA 35.1–35.76	Thu	16:00–18:00	P4	**Poster 2**
MA 36	Thu	18:00–19:00	H37	**Members' Assembly**
MA 37.1–37.13	Fri	9:30–12:45	H37	**Skyrmions 3 (joint session MA/KFM)**
MA 38.1–38.7	Fri	9:30–11:15	H43	**Electron Theory of Magnetism and Correlations**
MA 39.1–39.6	Fri	9:30–11:00	H47	**Magnetic Particles / Clusters**
MA 40.1–40.5	Fri	9:30–10:45	H48	**Weyl Semimetals**
MA 41.1–41.5	Fri	11:30–12:45	H47	**Micro- and Nanostructured Magnetic Materials**
MA 42.1–42.5	Fri	11:30–12:45	H48	**Magnetic Heuslers**

Members' Assembly of the Magnetism Division

Thursday 18:00–19:00 H37

MA 1: Tutorial: Careers in Science (joint session MA/TUT)

Time: Sunday 16:00–17:30 Location: H1

Tutorial MA 1.1 Sun 16:00 H1

Careers in science: "To boldly go where no one has gone before" — •Manfred Fiebig — Department of Materials, ETH Zurich

What does it take to do a career in science and become a university professor? An obvious answer is: you have to do outstanding research. But just doing great science plays a surprisingly small part — and what defines scientific work as outstanding anyway? Then, you also need to communicate your findings well. The best result is worth little if you present it in an awful talk or manuscript. You also need to be "good with people", may these be your students or your colleagues. Even luck can play an important role in a successful scientific career, but is very important to distinguish luck from "luck". I will refer to all these points and analyze what "being lucky" has actually to do with luck. I will present a list of points that I consider essential for a prosperous start into a scientific career. Some of these points are surprisingly unnoticed, so following them may put you ahead of the crowd.

Questions and discussion

MA 2: Magnetic Imaging Techniques

Time: Monday 9:30–10:30 Location: H37

MA 2.1 Mon 9:30 H37

High resolution magnetic imaging with holography-aided phase retrieval — •Riccardo Battistelli[1], Sergey Zayko[2], Michael Schneider[3], Christian M. Günther[4], Kathinka Gerlinger[3], Daniel Metternich[1], Lisa-Marie Kern[3], Kai Litzius[5], Stefan Eisebitt[3,4], Bastian Pfau[3], and Felix Büttner[1] — [1]Helmholtz-Zentrum Berlin, Berlin, Germany — [2]University of Göttingen, Göttingen, Germany — [3]Max Born Institute, Berlin, Germany — [4]Technische Universität Berlin, Berlin, Germany — [5]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany

In the fields of magnetism and spintronics, magnetic multilayers continue to thrive as pivotal structures to functionalize magnetic interactions and to engineer complex non-trivial spin textures. Despite the intense research on this topic, relatively little is known about 3D magnetic textures in multilayers and their interaction with local defects, despite the expected richer physics and potential in information technologies. The experimental challenges of studying such systems can be met by merging Fourier Transform Holography with phase retrieval algorithms for coherent diffractive imaging, obtaining high throughput, high resolution and high contrast images of magnetic materials. Here we present 5 nm resolution X-ray images of magnetic multilayers in which the presence of 3D magnetic defects can be inferred thanks to the high sensitivity of the technique. The interaction of magnetic domains with these defects favors the presence of domain walls, reducing the average domain size with respect to the pristine material.

MA 2.2 Mon 9:45 H37

Using electron microscopic methods to evaluate the magnetic proximity effect — •Daniela Ramermann[1,3], Inga Ennen[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 — [3]Max Planck Institute for Chemical Energy Conversion, Stiftstraße 34-36, 45470 Mülheim an der Ruhr

Magnetic proximity effects are part of spintronic, superconducting, excitonic and topological phenomena which can induce desired or parasitic effects in measurements and devices. They are induced by a ferromagnet in a layer of a material close to the Stoner criterion in proximity to the ferromagnet. Usually magnetic proximity effects are studied by X-ray techniques. Modern analytical electron microscopy can be used to analyse the same underlying effects as well as electronic structure properties of materials. Therefore, it can be used to investigate the proximity effect in thin film systems.

As a model system a V/Fe thin film sample has been chosen. The techniques of electron energy loss magnetic chiral dichroism (EMCD) and differential phase contrast (DPC) have been used in combination. EMCD is used to show the presence of a magnetic moment on the material and DPC to locate the magnetic induction with high accuracy. Thus, we were able to observe a magnetic proximity effect of about 1.5 nm in V, which is in agreement with X-Ray measurements.

MA 2.3 Mon 10:00 H37

Coherent Correlation Imaging: Resolving fluctuating states of matter — •Christopher Klose[1], Felix Büttner[2,3,4], Wen Hu[3], Claudio Mazzoli[3], Kai Litzius[2], Riccardo Battistelli[4], Ivan Lemesh[2], Jason M. Bartell[2], Mantao Huang[2], Christian M. Günther[5], Michael Schneider[1], Andi Barbour[3], Stuart B. Wilkins[3], Geoffrey S.D. Beach[2], Stefan Eisebitt[1,5], and Bastian Pfau[1] — [1]Max Born Institute, Berlin — [2]Massachusetts Institute of Technology, Cambridge, MA, USA — [3]National Synchrotron Light Source II, Upton, NY, USA — [4]Helmholtz-Zentrum Berlin — [5]Technische Universität Berlin

Fluctuations and stochastic transitions are ubiquitous in nanometer-scale systems, especially in the presence of disorder. However, their direct observation has so far been impeded by a seemingly fundamental, signal-limited compromise between spatial and temporal resolution.

Here, we develop coherent correlation imaging (CCI) — a high-resolution, full-field imaging technique that realizes multi-shot, time-resolved imaging of stochastic processes. The key of CCI is the classification of camera frames that correspond to the same physical state by combining a correlation-based similarity metric with powerful classification algorithm developed for genome research.

We apply CCI to study previously inaccessible magnetic fluctuations in a highly degenerate magnetic stripe domain state with nanometer-scale resolution. The spatiotemporal imaging reveals the transition network between the states and details of the magnetic pinning landscape which have been inaccessible so far.

MA 2.4 Mon 10:15 H37

Charge State Instabilities of shallow Nitrogen-Vacancy Centers in Diamond at Cryogenic Ultra-High-Vacuum Conditions — Domenico Paone[1,2,5], •Toni Hache[1,5], Jeffrey N. Neethirajan[1,2,5], Dinesh Pinto[1,3], Andrej Denisenko[2], Rainer Stöhr[2], Péter Udvarhelyi[4], Ádám Gali[4], Aparajita Singha[1], Jörg Wrachtrup[1,2], and Klaus Kern[1,3] — [1]Max Planck Institute for Solid State Research — [2]3rd Institute of Physics and Research Center SCoPE, University of Stuttgart — [3]Institute de Physique, École Polytechnique Fédérale de Lausanne — [4]Wigner Research Centre for Physics, Institute for Solid State Physics and Optics, Hungarian Academy of Sciences — [5]Equal contribution.

Nitrogen-vacancy (NV) centers in diamond have attracted an immense interest for non-invasive magnetic imaging and quantum sensing. All NV based magnetic sensing protocols rely on the negative charge state of this quantum sensor (NV^-). In this work we demonstrate dramatic charge state conversions within individual NV centers at cryogenic (4.7 K) and $2 \cdot 10^{-10}$ mbar ultra-high-vacuum (UHV) conditions. The NV centers are characterized based on autocorrelation measurements, ODMR contrast and emission spectra. Under these extreme conditions, each of these measurements indicate a significant decrease of the relative occupancy of the NV^- charge state. Furthermore, we note a slight recovery of the NV^- charge state by dosing water (H_2O) on top of the diamond surface under UHV conditions. These results indicate that controlled surface treatments are essential for implementing NV center based quantum sensing protocols at cryogenic-UHV conditions.

MA 3: Spin-Dependent Phenomena in 2D

Time: Monday 9:30–10:15 Location: H43

MA 3.1 Mon 9:30 H43

Noncollinear magnetism in a monolayer of two-dimensional $\mathbf{CrTe_2}$ — •Nihad AbuAwwad[1,2], Manuel dos Santos Dias[2,1], Hazem AbuSara[3], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany — [3]Department of Physics, Birzeit University, PO Box 14, Birzeit, Palestine

The discovery of two-dimensional (2D) van der Waals magnets opened unprecedented opportunities for the fundamental exploration of magnetism in quantum materials. Recently, thin $CrTe_2$ films were demonstrated to be ferromagnetic up to room temperature, with an intriguing dependence of the easy axis on the thickness of the material [1,2]. Using first principles, we show that the charge-density waves characterizing a single $CrTe_2$ give rise to spiral magnetism through the emergence of the Dzyaloshinskii-Moriya interaction (DMI). Utilizing atomistic spin dynamics, we perform a detailed investigation of the complex magnetic properties pertaining to this 2D material impacted by the presence of various types of charge density waves. Also, we study the electronic and magnetic properties of heterostructures consisting of a single $CrTe_2$ monolayer interfaced with either Graphene or hBN.

–Work funded by the Palestinian-German Science Bridge (BMBF–01DH16027) and SPP 2244 (project LO 1659/7-1).

[1] Zhang *et al.*, Nat. Commun. **12**, 2492 (2021); [2] Meng *et al.*, Nat. Commun. **12**, 809 (2021).

MA 3.2 Mon 9:45 H43

Electric-field control of the DMI in magnetic heterostructures — •Donya Mazhjoo, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

The use of external electric fields can extend the exploration of spintronic devices with a tunable Dzyaloshinskii-Moriya interaction (DMI) by allowing control of the interfacial DMI. Moreover, the magnetocrystalline anisotropy energy (MAE) changes as function of electric field intensity. By using density functional theory as implemented in the Fleur-code [1], we investigated the electric field effects on graphene (Gr) covered Co/Pt(111) heterostructures. Experiments show evidence of a sizable DMI at the Gr/Co interface which partially compensates the spin-orbit coupling induced DMI at the Co/Pt interface [2], which could make these structures susceptible to electric fields. To stimulate their influence, we sandwiched the film between two electrodes of opposite polarity. The self-consistent spin-spiral calculations were performed with these changed boundary conditions and spin-orbit effects were included in first order perturbation theory for the DMI and self-consistently for the MAE. We demonstrate that external fields lead to modulation of the spin-orbit induced quantities that allow a tuning of properties like domain wall widths or skyrmion radii. Support from the FLAG-ERA JTC 2019 grant SOgraphMEM is gratefully acknowledged.

[1] https://www.flapw.de
[2] F. Ajejas et al. Nano Lett. 2018, **18**, 5364-5372

MA 3.3 Mon 10:00 H43

Spinon induced drag in quantum spin liquid heterostructures — •Raffaele Mazzilli[1], Alex Levchenko[2], and Elio Koenig[1] — [1]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart, Germany — [2]Department of Physics, University of Wisconsin-Madison, Madison, Wisconsin 53706, USA

Several quantum spin liquid candidate materials, such as $\alpha RuCl_3$ and 1T-$TaSe_2$, are exfoliable, so that it is possible to investigate 2D samples which avoid the manifestation of bulk properties that might disrupt the quantum spin liquid phase. In this phase the material is a Mott insulator and therefore it is impenetrable to direct electric probes such as charge currents. Despite this, in this work we propose an experimental setup that will allow to use non-local electrical probes to gain information on the transport properties of a gapless quantum spin liquid. The proposed setup is a spinon induced drag experiment, that consists in interfacing two metallic films separated by a layer of a quantum spin liquid. A current is injected in one of the two layers (active layer) and a voltage is measured on the second (passive) metallic film. The overall momentum transfer mechanism is a two-step process mediated by the Kondo interaction between the local moments in the quantum spin liquid and the spins of the electrons. We calculate, both for a U(1) and a Z_2 spin liquids, the drag resistivity in the framework of the linearized quantum Boltzmann equation derived from the Keldysh formalism. In this framework the three layers are out of thermodynamic equilibrium. We further confront the results obtained with the equilibrium case and with the results of standard Coulomb drag.

MA 4: Disordered Magnetic Materials

Time: Monday 9:30–10:30 Location: H47

MA 4.1 Mon 9:30 H47

Destruction of long-range magnetic order in the $\mathbf{Cu_2GaBO_5}$ ludwigite in a magnetic field — A. Kulbakov[1], R. Sarkar[1], O. Janson[2], S. Dengre[1], E. M. Moshkina[3], P. Y. Portnichenko[1], H. Luetkens[4], F. Yokaichiya[5], A. S. Sukhanov[1,6], R. M. Eremina[7], A. Schneidewind[8], H.-H. Klauss[1], A. Korshunov[9], and •D. S. Inosov[1] — [1]TU Dresden, Germany — [2]IFW Dresden, Germany — [3]Krasnoyarsk, Russia — [4]PSI, Villigen, Switzerland — [5]HZB, Berlin, Germany — [6]MPI CPfS, Dresden, Germany — [7]Kazan, Russia — [8]JCNS @ MLZ, Forschungszentrum Jülich, Germany — [9]ESRF, Grenoble, France

The quantum spin system Cu_2GaBO_5 with the ludwigite structure consists of a structurally ordered Cu^{2+} sublattice interpenetrated by a disordered sublattice with a random site occupation by magnetic Cu^{2+} and nonmagnetic Ga^{3+}. In zero magnetic field, antiferromagnetic long-range order with the propagation vector $q_m = (0.45, 0, 0.7)$ sets in below $T_N = 4.1$ K, corresponding to a complex noncollinear structure with a large magnetic unit cell. Gapless spin dynamics in the form of a diffuse quasielastic peak is evidenced by neutron scattering. Remarkably, a magnetic field of ∼1 T destroys the static long-range order, which is manifested in the gradual broadening of magnetic Bragg peaks. Such a crossover to a spin-glass regime may result from orphan spins on the structurally disordered magnetic sublattice, which are polarized in magnetic field and act as a tuning knob for field-controlled magnetic disorder. For details, see Phys. Rev. B **103**, 024447 (2021).

MA 4.2 Mon 9:45 H47

Transport properties of FeAl under ion irradiation — •Serhii Sorokin[1], Gregor Hlawacek[1], Shadab Anwar[1], João Salgado-Cabaço[1], Richard Boucher[2], Kay Potzger[1], Jürgen Fassbender[1], Jürgen Lindner[1], and Rantej Bali[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Institute for Materials Science, Technische Universität Dresden, Dresden, Germany

In $Fe_{60}Al_{40}$ ion irradiation can be used to control the saturation magnetization (M_s) due to the gradual transition from paramagnetic (ordered B2-phase) to ferromagnetic (disordered A2-phase) as a function of ion fluence. The corresponding changes to the transport properties occurring during this phase transition are lesser known. Here we track the variation of electronic transport properties in parallel with gradual ion irradiation. A sample is inserted into a He/Ne-ion microscope on top of a permanent magnet and contacted with feedthrough probes to enable step-wise measurements during Ne^+-irradiation. The variation of the resistance and the Hall voltage are tracked as a function of the Ne^+-fluence, as the ordered B2 structure transforms into a disordered A2 structure. Peaks in the electrical resistance and the Hall voltage are observed corresponding to the existence of a partial B2/A2 state, thereby hinting at the important role of the induced ferromagnetic clusters and their distribution on the transport properties. The state of disorder is reversible by annealing with higher electric current.

Project funded by the DFG - 322462997 (BA 5656/1-2 | WE-

2623/14-2).

MA 4.3 Mon 10:00 H47

Magnetostructural phase transition in $Fe_{60}V_{40}$ alloy thin films — •Md Shadab Anwar[1,2], Hamza cansever[1], Benny Boehm[3], Rudolfo Gallardo[5], René Hübner[1], Shengqiang Zhou[1], Ulrich Kentsch[1], Benedikt Eggert[4], Simon Rauls[4], Heiko Wende[4], Kay Potzger[1], Jürgen Fassbender[1], Kilian Lenz[1], Jürgen Lindner[1], Olav Hellwig[1,3], and Rantej Bali[1] — [1]HZDR, Germany — [2]TU Dresden, Germany — [3]TU Chemnitz, Germany — [4]UDE Duisburg, Germany — [5]UTF Santa María, Chile

Ferromagnetism can be induced in non-ferromagnetic alloys such as B2 $Fe_{60}Al_{40}$[1] and B2 $Fe_{50}Rh_{50}$[2] through lattice disordering. Here we study a magnetostructural transition in $Fe_{60}V_{40}$ thin films using ion-irradiation. We show that the as-grown films possess an M_s of 17 kA/m and irradiation with 25 keV Ne^+-ions at a fluence of 5 x 10^{15}ions/cm^2 leads to an increase of M_s to $\sim$ 750 kA/m. A structural short-range order is observed in the as-grown films that transforms to A2 phase via ion-irradiation. Mössbauer spectroscopy and Ferromagnetic Resonance have been applied to track the variation of local magnetic ordering and dynamic behaviour respectively.

Financial support by DFG grants BA 5656/1-2 and WE 2623/14-2 is acknowledged.

[1]Ehrler, J.*et al., New J. Phys.*,22,073004(2020)
[2]Eggert, B.*et al., RSC Adv.*,10,14386(2020)

MA 4.4 Mon 10:15 H47

Understanding the ion induced reordering of amorphous $Fe_{60}V_{40}$ thin films — •Simon Rauls[1], Benedikt Eggert[1], Shadab Anwar[2], Damian Günzing[1], Philipp Klassen[1], Alexander Herman[1], Rantej Bali[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Interface Magnetism, Helmholtz-Zentrum Dresden-Rossendorf

For efficient spintronic devices, magnetic materials possessing both low moment and low Gilbert damping are highly demanded [1]. In this field, binary alloys consisting of Fe and easily polarizable elements like V are promising candidates, as they are reported to have a Gilbert damping parameter of $\alpha \sim 0.001$ which is about one order of magnitude lower as compared to the much-used permalloy [2]. Additionally, FeV can be grown as amorphous, paramagnetic thin films which reorder to the A2 structure upon ion irradiation. This can be exploited in such a way that ferromagnetic nanostructures can be written into the paramagnetic template in a single ion irradiation step using focussed ion beams or broad ion beams with masks.
Using Mössbauer spectroscopy and EXAFS, we will provide further insights into the reordering mechanics of amorphous $Fe_{60}V_{40}$ thin films by comparing the evolution of short range order and the hyperfine fields across the ion irradiation- and annealing-induced phase transition.

Funding by the Deutsche Forschungsgemeinschaft (DFG) - 322462997 (BA5656/1-2 WE 2623/14-2) is acknowledged.
[1] A. Barman et al. *J. Phys.: Condens. Matter* **33** 413001 (2021)
[2] D. Smith et al., *Phys. Rev. Applied* **14**, 034042 (2020)

MA 5: Magnetic Instrumentation and Characterization

Time: Monday 9:30–10:30 Location: H48

MA 5.1 Mon 9:30 H48

Cubic magneto-optic Kerr effect in Ni(111) thin films with and without twinning — •Maik Gaerner[1], Robin Silber[2], Tobias Peters[1], Jaroslav Hamrle[3], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]IT4Innovations, VŠB - Technical University of Ostrava, Czech Republic — [3]Charles University, Prague, Czech Republic

In most studies utilizing the magneto-optic Kerr effect (MOKE), the detected change of polarized light upon reflection from a magnetized sample is supposed to be proportional to the magnetization $\boldsymbol{M}$. However, MOKE signatures quadratic in $\boldsymbol{M}$ have also been identified and utilized, e.g., to sense the structural order in Heusler compounds [1]. In our study, we employ the eight-directional method [2] to separate different MOKE contributions in Ni(111) thin films. We observe a strong anisotropic longitudinal MOKE contribution of third order in $\boldsymbol{M}$ which we attribute to a cubic magneto-optic tensor proportional to $\boldsymbol{M}^3$ [3]. We further show that the angular dependence of cubic MOKE (CMOKE) is affected by the amount of structural domain twinning (two structural (111) phases with 60° in-plane rotation) in the sample [3]. Our detailed study on CMOKE for two selected photon energies will open up new opportunities for CMOKE applications with sensitivity to twinning properties of thin films, e.g. CMOKE spectroscopy and microscopy or time-resolved CMOKE.

[1] R. Silber et al., Appl. Phys. Lett. 116, 262401 (2020)
[2] K. Postava et al., J. Appl. Phys. 91, 7293 (2002)
[3] M. Gaerner et al., arXiv: 2205.08298 (2022)

MA 5.2 Mon 9:45 H48

A cryogen-free 10T asymmetric neutron scattering magnet with 50mm sample space and temperature range from 300mK to 375K — •Tom Ritman-Meer, Marc Savey-Bennett, and Roger Mitchell — Cryogenic Ltd, 6 Acton Park Estate, The Vale, London, W3 7QE, United Kingdom

Cryogenic Ltd has built and delivered a Cryogen-Free ring-separated magnet for polarised neutron scattering experiments with 10T central field and integral VTI cooled from a single 1.8W cryocooler.

The magnet has a novel dual power-supply control unit to provide an asymmetric field when required, allowing the twin requirements of minimal depolarisation and maximum homogeneity to be managed. The magnet consists of inner and outer pairs which are separately controlled to minimise the impact of the asymmetry. The zero field point can be shifted by up to 20mm from the central plane.

The system has a sample space of 50mm diameter, housed within a closed-cycle refrigeration system, offering a temperature controlled environment of 1.5K-375K. Sample exchange is into an inner *static column* eliminating the risk of accidental blockage.

The system includes a specially designed helium-3 insert with >40mm working space inside an aluminium IVC of just 1mm thick allowing continuous operation at 280mK for 76 hours within the main VTI space. Total aluminium in the beam path is limited to just 15mm (sample to outer wall).

The system also includes an automated z-axis and rotation manipulator stage for both the He-3 unit and standard sample probes.

MA 5.3 Mon 10:00 H48

Detection of nanowire vibrations with a co-resonantly coupled cantilever system — •Maneesha Sharma, Aniruddha Sathzadharma Prasad, Bernd Büchner, and Thomas Mühl — Leibniz Institute for Solid State and Materials Research, IFW Dresden, Germany

Nanowires can constitute the basis for high-sensitivity sensing of masses and magnetic properties of nanoparticles. We report a novel and efficient yet simple method for detecting nanowire flexural vibrations. In this work we present a co-resonantly coupled cantilever system consisting of a microcantilever and a nanocantilever. Achieving co-resonance involves matching the resonance frequencies of the individual systems. It allows us to measure the coupled system*s eigenmodes at the microcantilever. In the co-resonant state weak force gradients acting at the nanowire end have a considerable impact on the eigenmodes of the coupled system and thus can be easily sensed at the microcantilever.

We analyze mechanical properties of the nanowire subsystem and of the coupled system by exploiting thermally induced fluctuations which are measured by recording time-resolved secondary electron signals when using an electron beam and, in case of the microcantilever, by optical laser deflection. Finally, we discuss applications of the coupled cantilever sensor for high-sensitivity magnetometry.

MA 5.4 Mon 10:15 H48

A Ti/Pt/Co Multilayer Stack for Transfer Function Based Magnetic Force Microscopy Calibrations — •Baha Sakar[1], Sibylle Sievers[1], Osman Öztürk[2], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Gebze Technical University, Kocaeli, Turkey

Magnetic force microscopy (MFM) is a widespread technique for imaging magnetic structures with a resolution of some 10 nanometers.

MFM can be calibrated to obtain quantitative (qMFM) spatially resolved magnetization data in units of A/m by determining the calibrated point spread function of the instrument, its instrument calibration function (ICF), from a measurement of a well-known reference sample. Beyond quantifying the MFM data, a deconvolution of the MFM image data with the ICF also corrects the smearing caused by the finite width of the MFM tip stray field distribution. However, the quality of the calibration depends critically on the calculability of the magnetization distribution of the reference sample. Here, we discuss a Ti/Pt/Co multilayer stack that shows a stripe domain pattern as a suitable reference material. A precise control of the fabrication process, combined with a characterization of the sample micromagnetic parameters, allows reliable calculation of the sample*s magnetic stray field, proven by a very good agreement between micromagnetic simulations and qMFM measurements. A calibrated qMFM measurement using the Ti/Pt/Co stack as a reference sample is shown and validated, and the application area for quantitative MFM measurements calibrated with the Ti/Pt/Co stack is discussed.

MA 6: Complex Magnetic Oxides

Time: Monday 11:00–12:00 Location: H37

MA 6.1 Mon 11:00 H37

Polaronic behavior in $La_{1.2}Sr_{1.8}Mn_2O_7$ — •Daniel Jost[1], Matteo Rossi[1], Hsiao-Yu Huang[2], Amol Singh[2], Di-Jing Huang[2], Yonghun Lee[1,3], Brian Moritz[1], John Mitchell[4], Zhi-Xun Shen[1,3,5,6], Thomas Devereaux[1,7], and Wei-Sheng Lee[1] — [1]Stanford Institute for Materials and Energy Sciences, Menlo Park, USA — [2]National Synchrotron Radiation Research Center, Hsinchu, TW — [3]Department of Physics, Stanford University, Stanford, USA — [4]Materials Science Division, ANL, Lemont, USA — [5]Department of Applied Physics, Stanford University, USA — [6]Geballe Laboratory for Advanced Materials, Stanford University, USA — [7]Department of Materials Science and Engineering, Stanford Univeristy, USA

The microscopic mechanism driving colossal magneto-resistance (CMR) remains controversial. In $La_{1.2}Sr_{1.8}Mn_2O_7$, CMR is most pronounced at its insulator to ferromagnetic-metal transition at $T_c = 120\,K$. In this compound, initial ARPES studies revealed the abrupt formation of quasi-particles having a strong mass renormalization below T_c, subsequently interpreted as the condensation of localized polarons into a coherent polaronic liquid. Yet, conflicting results showing finite quasi particle spectral weight above T_c cast doubt on this scenario. Here we use resonant inelastic X-ray scattering (RIXS) to investigate this controversy. In contrast to ARPES which measures the single particle spectral function, RIXS probes collective excitations directly and is thus especially suitable for the investigation of charge-lattice coupled phenomena. In this presentation, I will discuss the RIXS signatures of polarons in $La_{1.2}Sr_{1.8}Mn_2O_7$.

MA 6.2 Mon 11:15 H37

Magneto-optic Kerr effect in ferromagnetic manganite multilayers — •Jörg Schöpf, Paul H.M. van Loosdrecht, and Ionela Lindfors-Vrejoiu — Universität zu Köln, II. Physikalisches Institut, Zülpicherstr. 77, 50937 Köln (DE)

Magnetic functional oxide epitaxial thin films and heterostructures offer a rich variety of physical properties due to lattice mismatch induced strain, interfacial effects and interlayer coupling between different ferromagnetic (FM) layers. The magneto-optic Kerr effect (MOKE) can be used as an indirect probe of the magnetization of a sample. The MOKE of a material is wavelength dependent, and is non-monotonic in the vicinity of MO-active transitions, where the Kerr rotation can change sign and even vanish at particular wavelengths. Knowledge of the wavelength dependence can help to distinguish the contributions of different FM layers within a multilayer to the total measured Kerr effect. Here we present a study on the MOKE of a heterostructure of 10% Ru-doped La0.7Sr0.3MnO3 (LSMRO), where the layers are of different thickness (30 nm bottom layer and a 10 nm top layer), and separated by a NdNiO3 spacer. We found that the measured Kerr hysteresis loops of the heterostructure have an anomalous shape originating from a different sense of rotation of the MOKE from the different LSMRO layers. This can readily be described by Kerr-loops measured on reference samples using the additivity of the MOKE in multilayer systems.

MA 6.3 Mon 11:30 H37

Strain-induced ferromagnetism in LaCoO3 thin film — •Farzin Abadizaman, Michal Kiaba, and Adam Dubroka — Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic.

Ellipsometry measurements were performed on unstrained, tensile strained, and compressive strained LaCoO3 thin films. Only the tensile strained sample shows ferromagnetism, which has a Currie temperature of about 85 K. Using the differential optical conductivity, $\delta\sigma_1 = \sigma_1(T) - \sigma_1(T = 7K)$, we find that in the tensile strain sample, while the spectral weight $N_{eff} = 2mV/\pi e^2 \int \sigma_1(\omega), d\omega$ below 3.5 eV decreases with decreasing temperature in the paramagnetic phase, it starts increasing in the ferromagnetic phase below the transition temperature. This is the first time that the ferromagnetism in this material is observed via optical measurements, and we interpret the results as stabilization of the high-spin state in the ferromagnetic phase associated with transition of spectral weight from higher to lower energy region.

MA 6.4 Mon 11:45 H37

Spin-Orbit Excitations in a Strongly Correlated 4d-Metal Studied by Resonant Inelastic X-ray Scattering — •Valentin Zimmermann[1], Deniz Wong[2], Christian Schulz[2], Maciej Bartkowiak[2], Klaus Habicht[2], Arvind Yogi[3], Masahiko Isobe[1], Lichen Wang[1], Matteo Minola[1], Giniyat Khalliulin[1], Bernhard Keimer[1], and Matthias Hepting[1] — [1]Max-Planck-Institute for Solid State Research, Stuttgart, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]UGC-DAE-Consortium for Scientific Research, Indore, India

Spin-orbit coupling (SOC) is an important player determining the electronic and magnetic properties of $4d$ and $5d$ transition metal oxides. The $5d$ compound Sr_2IrO_4 is an antiferromagnetic Mott insulator, where SOC leads to a splitting of the t_{2g} manifold into bands with effective total angular momentum $J_{eff} = 3/2$ and $1/2$. This electronic structure gives rise to low-energy excitations with excitonic character, which were recently studied by resonant inelastic X-ray scattering (RIXS) and assigned to the transition of holes across the spin-orbit split states. Here, we use RIXS at the oxygen K-edge to investigate the isovalent $4d$ compound Sr_2RhO_4, which is a paramagnetic, strongly correlated metal. We observe similar spin-orbit excitons as in Sr_2IrO_4, however, on a smaller energy scale and with a distinct dispersion, which we attribute to a reduced SOC strength and the metallic ground state, respectively. In addition, we explore whether the solid-solution $Sr_2Rh_{1-x}Ir_xO_4$ is a viable platform to tune the effective strength of SOC.

MA 7: Magnetic Relaxation and Gilbert Damping

Time: Monday 11:00–12:00 Location: H43

MA 7.1 Mon 11:00 H43

Strong photon-magnon-coupling between superconducting niobium lumped-element-resonators and micron sized magnets — •Philipp Geyer[1], Philip Trempler[1], Karl Heimrich[1], and Georg Schmidt[1,2] — [1]1Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany — [2]2Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Nanotechnikum Weinberg, 06120 Halle (Saale), Germany

Since quantum computing plays a more and more important role in information technology hybrid quantum magnonics emerge as a promising research field. Here, the coupling between different quantum states like microwave photons and magnons at cryonic temperatures is in focus [1]. We investigate the coupling between superconducting niobium Lumped-Element-Resonators and thin micron-sized magnetic structures. Therefore, we use the magnetic material permalloy and yttrium-iron-garnet (YIG). Permalloy was structured by optical lithography and grown by argon-ion sputtering at room-temperature. YIG was grown as free standing structure [2] or commercial LPE film and further processed and placed on the cavity by focused-ion-beam technique. We detect strong coupling as avoided crossing in the transmission related S-Parameter measured by a vector-network-analyzer. For validation of our experimental results, we perform electromagnetic simulations with CST Studio Suite and micromagnetic simulations with MuMax3. [1] H. Huebl et.Al. Phys. Rev. Lett. 111, 127003 (2013) [2] P. Trempler et. Al. Appl. Phys. Lett. 117, 232401 (2020) 401 (2020)

MA 7.2 Mon 11:15 H43

Magnetization dynamics affected by phonon pumping — •Richard Schlitz[1], Luise Siegl[2], Takuma Sato[3], Weichao Yu[4], Gerrit E. W. Bauer[3], Hans Huebl[5], and Sebastian T. B. Goennenwein[2] — [1]Department of Materials, ETH Zürich, 8093 Zürich, Switzerland — [2]Department of Physics, University of Konstanz, 78457 Konstanz, Germany — [3]Tohoku University, Sendai 980-8577, Japan — [4]State Key Laboratory of Surface Physics and Institute for Nanoelectronic Devices and Quantum Computing, Fudan University, Shanghai 200433, China — [5]Walther-Meißner-Institute, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany

Coupling magnetic and acoustic excitations enables novel functionalities for magnonic devices. We explore broadband ferromagnetic resonance (FMR) in a $Y_3Fe_5O_{12}$ film on a $Gd_3Ga_5O_{12}$ substrate. At low frequencies, the Kittel mode hybridizes with standing ultrasound waves that form across the layer stack resulting in a characteristic modification of the magnetic susceptibility. At higher frequencies, the individual phonon resonance overlap, leading to a permanent emission of phonons and thus an enhanced relaxation of the FMR. The broadband frequency dependence of the magnetoelastic coupling and thus the phonon pumping follows theoretical predictions. We additionally find substantial magnon-phonon coupling of a perpendicular standing spin wave mode. This evidences the importance of the mode overlap between the acoustic and magnetic modes and thus paves the way to tailoring the magnetoelastic mode coupling.

[1] R. Schlitz et al., arxiv:2202.03331 (2022)

MA 7.3 Mon 11:30 H43

Gilbert damping in the real-space KKR method — Balázs Nagyfalusi[1], László Szunyogh[2], and •Krisztián Palotás[1,2] — [1]Wigner Research Center for Physics, Budapest, Hungary — [2]Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

The ab-initio determination of Gilbert damping parameters is an important issue for accurate atomistic spin dynamics calculations. Going beyond presently available methods of calculating the Gilbert damping scalar parameter in bulk materials, we implemented the torque-torque correlation formula [1] into the real-space Korringa-Kohn-Rostoker (KKR) method [2] using the Budapest SKKR code to be able to treat chemically inhomogeneous systems. This enables the ab-initio determination of spatially resolved on-site and non-local Gilbert damping tensors [3] in atomic nanostructures. After performing extensive tests for metallic bulk materials to identify the relevant parameter settings of the calculations, we show some examples of inhomogeneous Gilbert damping results in various metallic atomic (nano-)structures.

[1] H. Ebert et al., Phys. Rev. Lett. 107, 066603 (2011). [2] B. Lazarovits et al., Phys. Rev. B 65, 104441 (2002). [3] D. Thonig et al., Phys. Rev. Mater. 2, 013801 (2019).

MA 7.4 Mon 11:45 H43

Bath-induced spin inertia — Mario A. Gaspar Quarenta[1], •Tim Ludwig[1], Huaiyang Yuan[1], and Rembert A. Duine[1,2] — [1]Institute for Theoretical Physics, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands — [2]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

In spintronics, magnetization dynamics is often described by the Landau-Lifshitz-Gilbert equation, where Gilbert damping is included phenomenologically to account for dissipation. In microscopic models, dissipation can be described by coupling the magnetization to a bath that can absorb energy and angular momentum. Gilbert damping is then obtained if one assumes the bath to be Ohmic; that is, if one assumes the bath spectral density to be linear in frequency. Real baths, however, can be Ohmic only at low frequencies and, as we will argue, the baths' high-frequency modes induce magnetization inertia. Explicitly, we show for a macrospin coupled linearly to a bath of harmonic oscillators (Caldeira-Leggett model) that the low-frequency bath modes (if Ohmic) lead to Gilbert damping while the high-frequency bath modes universally lead to macrospin inertia. We expect our results to give new insights into recent experiments on magnetization nutation. But our results might prove to be relevant in general, as they indicate that a Gilbert-damping term should always be accompanied by a term accounting for bath-induced spin inertia.

MA 8: Ultrafast Magnetization Effects 1

Time: Monday 15:00–18:00 Location: H37

MA 8.1 Mon 15:00 H37

Spectrally resolved spin dynamics of 3d transition metals in EUV T-MOKE — •Henrike Probst[1], Christina Möller[1], Mariana Brede[1], Maren Schumacher[1], Karen Stroh[1], Marcel Reutzel[1], G. S. Matthijs Jansen[1], Sangeeta Sharma[2], Daniel Steil[1], and Stefan Mathias[1] — [1]I. Physikalisches Institut, University of Göttingen — [2]Max-Born-Institute for Non-linear Optics and Short Pulse Spectroscopy, Berlin

Light in the extreme ultraviolet (EUV) range has found increasing application in the field of magneto-optical spectroscopy. It allows to get new insights in light-matter interaction processes, as EUV spectroscopy provides the potential to investigate energy- and element-resolved spin dynamics [1-2].

Here, we carry out a comprehensive study of spectrally resolved spin dynamics of the 3d transition metals Co, Fe and Ni using EUV transverse magneto-optical Kerr spectroscopy (T-MOKE) [3]. Covering the M-edges in the 30-72 eV energy window, this allows to resolve spin dynamics at specific energies around the Fermi-level. We discuss different processes leading to energy dependent changes in the magnetic asymmetry at early times after the optical excitation, i.e. charge excitation and band renormalization.

[1] Hofherr et al., Sci. Adv. 6.3 (2020): eaay8717.
[2] Tengdin et al., Sci. Adv. 6.3 (2020): eaaz1100.
[3] Möller et al., Rev. Sci. Instrum., 92(6) (2021): 065107.

MA 8.2 Mon 15:15 H37

Ultrafast element- and depth-resolved magnetization dynamics probed by transverse magneto-optical Kerr effect spectroscopy in the soft x-ray range — •Martin Hennecke[1], Daniel Schick[1], Themistoklis Sidiropoulos[1], Felix Willems[1], Anke

Heilmann[1], Martin Bock[1], Lutz Ehrentraut[1], Dieter Engel[1], Piet Hessing[1], Bastian Pfau[1], Martin Schmidbauer[2], Andreas Furchner[3,4], Matthias Schnuerer[1], Clemens von Korff Schmising[1], and Stefan Eisebitt[1,5] — [1]Max-Born-Institut, Berlin, Germany — [2]Leibniz-Institut für Kristallzüchtung, Berlin, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany — [4]Leibniz-Institut für Analytische Wissenschaften, Berlin, Germany — [5]IOAP, Technische Universität Berlin, Berlin, Germany

Understanding the light-driven spin dynamics occurring at buried interfaces of complex magnetic heterostructures as used in today's opto-spintronics applications requires direct experimental access to the nonlocal magnetic order on sub-ps time scales. Here, we report on broadband time- and angle-resolved transverse magneto-optical Kerr effect spectroscopy probing the Gd $N_{5,4}$ resonance (≈150 eV) of a ferrimagnetic GdFe nanostructure with fs soft x-ray pulses provided by a laboratory-scale light source based on high-harmonic generation. Employing a pump-probe technique, we follow the fs laser-induced demagnetization of the GdFe layer. Analyzing the fs time-resolved spectra via magnetic scattering simulations allows a quantitative determination of the transient magnetization depth profiles evolving within the magnetic film due to strongly layer-dependent photoexcitation.

MA 8.3 Mon 15:30 H37

Table-top X-ray magnetic circular dichroism at the Fe L edges
— •Martin Borchert[1,2], Daniel Schick[1], Clemens v. Korff Schmising[1], Denny Sommer[1], Dieter Engel[1], Bastian Pfau[1], and Stefan Eisebitt[1,2] — [1]Max-Born-Institut, Berlin — [2]TU Berlin

Time-resolved X-ray magnetic circular dichroism (XMCD) is a powerful tool to directly probe the element-specific magnetization in multicomponent heterostructures.

Due to the lack of laboratory-scale light sources with sufficient brightness and control over the light's polarization, static and time-resolved XMCD studies in the higher soft X-ray photon energy range have so far been limited to large-scale facilities such as synchrotrons and free-electron lasers.

Here, we present first XMCD spectroscopy data recorded at the Fe $L_{3,2}$ resonances employing a laboratory-scale soft X-ray source utilizing a magnetic thin-film polarizer to circularly polarize the soft X-rays from the continuous, broadband (50–1500 eV) emission of a laser-driven plasma source with <10 ps pulse duration. A reflection zone plate (RZP) is used as the single optical element to collect, disperse and focus the full spectrum across the Fe L edges through a thin-film sample, to which an external magnetic field can be applied to observe the resulting asymmetry spectrum, as well as hysteresis loops.

Utilizing different RZPs, this setup enables the first laboratory-based whitelight XMCD spectroscopy with picosecond time resolution, covering the full spectrum of the magnetically relevant resonances from the transition metal M and L edges up to the rare earth M edges.

MA 8.4 Mon 15:45 H37

Temperature dependence of spin interaction parameters in two-sublattice ferrimagnets
— •Levente Rózsa[1], Severin Selzer[1], Niklas Windbacher[1], Ulrich Nowak[1], and Unai Atxitia[2] — [1]University of Konstanz, Konstanz, Germany — [2]Instituto de Ciencia de Materiales de Madrid, Madrid, Spain

Ferrimagnets consist of two antiferromagnetically coupled sublattices with different magnetic moments, thereby possessing a finite magnetization like ferromagnets. The ferrimagnet magnetite has been known since ancient times, yet ferrimagnets continue to attract research interest in various areas of spintronics from magnons to skyrmions. The properties of ferrimagnets may be tuned between those of ferromagnets and antiferromagnets by changing the temperature. Therefore, determining the temperature dependence of model parameters of ferrimagnets is essential for their accurate description.

Here we present an analytical method for describing the temperature dependence of spin interactions in ferrimagnets, based on Callen's Green's function formalism [1]. The temperature dependence of the Heisenberg and Dzyaloshinsky-Moriya interactions, as well as of the anisotropy terms are derived and compared to known expressions in ferromagnets [2,3]. The role of spin correlations is highlighted in reduced dimensions. The results are compared to numerical simulations of the magnon frequencies and of reversal times of nanoparticles.

[1] H. B. Callen, Phys. Rev. 130, 890 (1963).
[2] L. Rózsa et al., Phys. Rev. B 96, 094436 (2017).
[3] R. F. L. Evans et al., Phys. Rev. B 102, 020412(R) (2020).

MA 8.5 Mon 16:00 H37

Electron-Magnon Scattering Dynamics in a two-band Stoner Model
— •Félix Dusabirane, Kai Leckron, Sanjay Ashok, Bärbel Rethfeld, and Hans Christian Schneider — Physics Department & Research Center OPTIMAS, University of Kaiserslautern, Germany

We use a microscopic model to study carrier dynamics in ferromagnets due to electron-magnon scattering on ultrafast timescales. We employ a simple model band structure (Stoner model), for which the electron magnon-interaction is formally obtained as coupling to a Heisenberg spin system in the Hamiltonian. We compute the dynamics of momentum resolved electron and magnon distributions due to electron-magnon and statically screened electron-electron scattering, which are treated at the level of Boltzmann scattering integrals. We find that electron-magnon scattering leads to a pronounced non-equilibrium for magnon modes that couple directly to Stoner transitions. The spin-flip scattering with electrons results in a transient electron spin polarization, which is similar for excitations either within the minority or the majority band. The influence of model parameters such as band filling and exchange coupling strengths will be discussed.

MA 8.6 Mon 16:15 H37

Ultrafast optical generation of antiferromagnetic spin texture
— •Sumit Ghosh[1,2], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]PGI1, Forschungszentrum Jülich, Germany. — [2]Institute of Physics, Johannes Gutenberg-University Mainz, Germany.

We present here an unified picture of ultrafast manipulation of collinear antiferromagnetic order by combining both electronic and magnetic degrees of freedom via a hybrid quantum classical evolution scheme. Our approach allows us to probe slow magnetic relaxation for several picoseconds with a sub-femtosecond resolution and thus allows us to identify the emergent interactions driving the formation of nontrivial textures which remains hidden from classical magnetisation dynamics. In case of a one dimensional spin chain this mechanism can lead to the formation of spin spirals [1] where the induces chirality can be tuned with the laser parameter. In case of two dimensional antiferromagnets this mechanism can lead to more exotic outcome - generation of a texture and anti-texture which can survive for 100ps [2] and is fairly robust against impurity. Our results thus opens new possibilities to generate higher order nontrivial magnetic texture with ultrafast laser.

[1] S. Ghosh, et.al. Communications Physics, 5(1), 69, 2022. https://doi.org/10.1038/s42005-022-00840-3
[2] S. Ghosh, S. Blügel and Y. Mokrousov. arXiv:2205.12100. http://arxiv.org/abs/2205.12100

MA 8.7 Mon 16:30 H37

Polarized phonons carry the missing angular momentum in femtosecond demagnetization
— •Hannah Lange[1], Martin Evers[1], Andreas Donges[1], Sonja Tauchert[1,2], Mikhail Volkov[1,2], Peter Baum[1,2], and Ulrich Nowak[1] — [1]University of Konstanz, Fachbereich Physik, 78464 Konstanz — [2]LMU Munich, Am Coulombwall 1, 85748 Garching

When a thin nickel film is subjected to ultrashort laser pulses, it can lose its magnetic order almost completely on within hundreds of femtoseconds. This phenomenon offers opportunities for rapid information processing or ultrafast spintronics. However, a crucial question has remained elusive: Where is the angular momentum transferred to in such short time? Here we use molecular dynamics simulations to investigate the role of phonon angular momentum. When exciting a rotational lattice motion which carries the amount of angular momentum corresponding to the demagnetization, we observe an anisotropy of the atoms' velocities which violates the equipartition theorem. When calculating the corresponding electron diffraction pattern, this results in an anisotropy of normally equivalent Bragg spots. This is in line with ultrafast electron diffraction which show an almost instantaneous, long-lasting, non-equilibrium population of phonons. Theory and experiment hence indicate the formation of polarized phonons that take up the missing angular momentum [1] before the onset of a macroscopic Einstein-de Haas rotation [2].

[1] Tauchert et al. Nature 602, 73-77 (2022).
[2] Dornes et al. Nature 565, 209-212 (2019).

MA 8.8 Mon 16:45 H37

Does the orbital angular momentum of light affect ultrafast demagnetization?
— •Eva Prinz[1], Benjamin Stadtmüller[1,2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany

Optical fields can carry an orbital angular momentum (OAM) in helical beams with an azimuthal phase dependence. Since its discovery in 1992 [1], there has been a variety of applications of light with additional OAM, such as quantum entanglement, micro manipulation, communication, and microscopy [2].

Our research is focused on exploring the potential effects of the OAM of light on laser-induced ultrafast demagnetization. In this field, the question of how the angular momentum is conserved during spin-flips is not fully answered. Pumping the system with photons carrying OAM offers the potential to provide new insights, not only into the dissipation of angular momentum in the material but also into the interaction of photonic OAM with matter in general.

We investigate ultrafast demagnetization of ferromagnetic thin films induced by OAM light with time-resolved magneto-optic Kerr-effect measurements. We observed peculiar demagnetization dynamics that have so far not been observed for light without OAM.

[1] Allen et al., Phys. Rev. A 45 (1992)
[2] Shen et al., Light: Science & Applications 8 (2019)

MA 8.9 Mon 17:00 H37

Role of diffusive transport in ultrafast demagnetization dynamics — •Sanjay Ashok, Sebastian T. Weber, Christopher Seibel, Johan Briones, and Bärbel Rethfeld — Fachbereich Physik and OPTIMAS Research Center, TU Kaiserslautern, Kaiserslautern, Germany

Ultrafast demagnetization dynamics in thick metallic magnetic films is greatly influenced by transport processes. In this contribution we present the space-resolved magnetization dynamics in a thick Nickel film induced by a femtosecond laser pulse [3]. Starting from the thermodynamic μT-model [1], we explicitly include diffusive heat transport, spin-resolved charge transport, as well as Seebeck and Peltier effects.

Our results show that the spatial dependence of maximal magnitude of quenching is induced by a depth-dependent energy deposition and is only moderately equilibrated by transport processes. We reveal a stronger influence of transport on the time of quenching which becomes nearly independent of depth [3].

Additionally, we present the influence of pump-wavelength [2] on spatially resolved magnetization dynamics.

[1] B.Y. Mueller and B. Rethfeld, Phys. Rev. B. 90, 144420 (2014)
[2] U. Bierbrauer et al., JOP Cond. Mat., 29 (24), 244002 (2017)
[3] S. Ashok et al., Appl. Phys. Lett. 120, 142402 (2022)

MA 8.10 Mon 17:15 H37

Spin fluctuations around a reorientation transition in $Sm_{0.7}Er_{0.3}FeO_3$ — •Julius Schlegel[1], Martin Evers[1], Tobias Dannegger[1], Andreas Donges[1], Marvin Weiss[1], Takayuki Kurihara[2], Sebastian T.B. Goennenwein[1], and Ulrich Nowak[1] — [1]Department of Physics, University of Konstanz — [2]ISSP, University of Tokyo

The competition between thermal fluctuations, spin-spin interactions and magnetic anisotropies can lead to various magnetic phase transitions. For example the antiferromagnetic orthoferrite $Sm_{0.7}Er_{0.3}FeO_3$ undergoes a reorientation transition at approximately room temperature. On the basis of an atomistic spin model and the Landau-Lifshitz-Gilbert equation of motion we numerically calculate the time evolution of the magnetization around the reorientation transition on a timescale from picoseconds up to one nanosecond and investigate the thermal fluctuations of the magnetization. By Fourier-transforming the time dependent magnetization we find that the spectra of the noise are temperature dependent and change significantly while going through the reorientation. We also observe several resonances in the spectra. By means of analytical calculations based on linear spin wave theory these peaks can be assigned to the different modes of a model with four sublattices.

Finally, these results are compared to current experimental data from spin noise measurements.

MA 8.11 Mon 17:30 H37

Ultrafast spin dynamics: complementing theoretical analyses by quantum state measures — Franziska Ziolkowski, •Oliver Busch, Jürgen Henk, and Ingrid Mertig — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

In theoretical studies of ultrafast spin dynamics, one usually analyses and discusses observables — such as magnetization. On top of this, quantum state (QS) measures defined for density matrices may provide additional valuable insights into the dynamics [1].

We report on a study on QS measures that complement simulations of ultrafast spin dynamics [2]. For a Co/Cu heterostructure which is excited by a femtosecond laser pulse and coupled to a bosonic heat bath, we discuss the time dependence of QS measures, in particular distances in Hilbert space and degree of purity in the density matrix [3].

We identify observables and modifications of the investigated system to which both the distance and the purity measures are in particular sensitive: the polarization of the laser pulse and the composition of the sample. In contrast, temperature and photon energy affect the QS measures mildly. Our study shows that QS measures are complementary and beneficial quantities for spin dynamics simulations.

[1] S. Barnett, *Quantum Information* (Oxford University Press, Oxford, 2009)
[2] F. Töpler *et al.*; New Journal of Physics **23**, 033042 (2021)
[3] R. Jozsa, Fidelity for Mixed Quantum States, Journal of Modern Optics **41**, 2315 (1994)

MA 8.12 Mon 17:45 H37

Tuning all-optical magnetization switching efficiency by laser pulse wavelength variation — •Marcel Kohlmann[1], Lucas Vollroth[1], Kristýna Hovořaková[2], Eva Schmoranzerová[2], Robin John[1], Denise Hinzke[4], Peter Oppeneer[3], Ulrich Nowak[4], Markus Münzenberg[1], and Jakob Walowski[1] — [1]Greifswald University, Greifswald, Germany — [2]Charles University, Prague, Czech Republic — [3]Uppsala University, Uppsala, Sweden — [4]Konstanz University, Konstanz, Germany

Heat-assisted magnetic recording (HAMR) presents a promising candidate for high data density devices. Leaving investigation of magnetization manipulation a topic of interest for research and development. We study all-optical helicity-dependent switching of FePt granular HAMR media[2] as an alternative writing mechanism. The latest perception of interaction of heating and ultra fast excitation suggests the contribution of magnetic dichroism and the inverse Faraday effect as interchanging driving forces behind the magnetization reversal. The switching rates for individual FePt nano particles from ab-initio calculations of the inverse Faraday effect and magnetic dichroism induced heating provide a model to describe the switching as a stochastic process. We extend the study to wavelength dependent switching experiments from 800 nm up to 1550 nm for all-optical writing experiments on FePt granular media evaluating the writing efficiency.

We greatly acknowledge the DFG funding within the project "Fundamental aspects of all-optical single pulse switching in nanometer-sized magnetic storage media.

MA 9: INNOMAG e.V. Prizes 2022 (Diplom-/Master and Ph.D. Thesis)

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Dissertationspreis und einen einen Diplom-/Masterpreis ausgeschrieben, welche auf der Tagung der DPG 2022 in Regensburg vergeben werden. Ziel der Preise ist die Anerkennung herausragender Forschung im Rahmen einer Diplom-/Masterarbeit beziehungsweise einer Promotion und deren exzellente Vermittlung in Wort und Schrift. Im Rahmen dieser Sitzung tragen die besten der für ihre an einer deutschen Hochschule durchgeführten Diplom-/Masterarbeit beziehungsweise Dissertation Nominierten vor. Im direkten Anschluss entscheidet das Preiskommittee über den Gewinner des INNOMAG e.V. Diplom/Master-Preises und des Dissertationspreises 2022. Talks will be given in English!

Time: Monday 15:00–17:00 Location: H43

MA 9.1 Mon 15:00 H43

Magnetoelastic coupling and uniaxial pressure dependencies in the honeycomb quantum magnets CrI_3 and $Na_2Co_2TeO_6$ — •Jan Arneth[1], Martin Jonak[1], Mahmoud Abdel-Hafiez[2], Kwang-Yong Choi[3], and Rüdiger Klingeler[1] — [1]Kirchhoff-Institute for Physics, Heidelberg University, Germany — [2]Dep. of Physics and Astronomy, Uppsala University, Sweden — [3]Dep. of Physics, Sungkyunkwan University, Republic of Korea

Due to their layered structure, competing magnetic interactions, and magnetic anisotropy, quasi-2D honeycomb systems are promising quantum materials featuring fundamentally and technologically relevant phenomena. Often, relevant materials are at the verge of the desired properties, and strain has been proven to be a tuning parameter. Strain engineering of the critical temperature in 2D ferromagnetic semiconductors such as CrI_3 [1] towards room temperature or driving the quantum magnet $Na_2Co_2TeO_6$ into the Kitaev spin-liquid phase are illustrative examples. The precise determination of uniaxial strain effects is hence a mandatory step towards new applications and phenomena. We report dilatometric studies on the honeycomb quantum magnets CrI_3 and $Na_2Co_2TeO_6$ at low temperatures and high magnetic fields. Our data enable us to quantify magnetoelastic coupling and the uniaxial pressure dependencies of the respective ordering temperatures. Additionally, the magnetic phase diagrams are constructed, including structural response of the surface phase in CrI_3 and signatures of competing degrees of freedom in $Na_2Co_2TeO_6$.

[1] J. Arneth et al., Phys. Rev. B 105, L060404 (2022)

MA 9.2 Mon 15:20 H43

Magnetisation dynamics in epitaxial Co_2Mn-based Heusler thin films with ultralow damping for thicknesses below 50 nm — •Anna M. Friedel[1,2], Claudia de Melo[2], Victor Palin[2,3], Sébastien Petit-Watelot[2], Stéphane Andrieu[2], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institut Jean Lamour, UMR CNRS 7198, Université de Lorraine, Nancy, France — [3]Synchrotron SOLEIL-CNRS, L'Orme des Merisiers, Gif-sur-Yvette, France

For future applications of magnetisation dynamics, materials with low Gilbert damping are indispensable. Co_2Mn-based Heusler compounds are considered excellent candidates as they combine high saturation magnetisation, high Curie temperature, half-metallicity and ultralow Gilbert damping, especially when grown epitaxially with decent control over stoichiometry to ensure the desired chemical ordering [1]. However, downscaling towards microstructures is a challenge in which the fabrication of high-quality ultrathin films with consistent excellent properties is a crucial step. We succeeded in the epitaxial growth of high-quality Co_2MnSi Heusler films in the thickness range of 4-44 nm for all of which the half-metallicity was confirmed [2]. Consequently, an ultralow Gilbert damping was obtained for the whole series reaching down to 7.8×10^{-4} for the 8 nm film. Coupling effects and magnetisation dynamics in heterostructures are currently under investigation.

[1] C. Guillemard, *et al.*, J. Appl. Phys. **128**, 241102 (2020)
[2] C. de Melo, *et al.*, Appl. Mater. Today **25**, 101174 (2021)

MA 9.3 Mon 15:40 H43

ΔE-Effect Magnetic Field Sensors — •Benjamin Spetzler, Elizaveta Golubeva, Patrick Wiegand, Robert Rieger, Jeffrey McCord, and Franz Faupel — Kiel University, Kiel, Germany

Many conceivable biomedical and diagnostic applications require the detection of small-amplitude and low-frequency magnetic fields. Against this background, we investigate a magnetometer concept based on the magnetoelastic ΔE effect. The ΔE effect causes the resonance frequency of a magnetoelastic resonator to detune in the presence of a magnetic field, which can be read out electrically with an additional piezoelectric phase. Various microelectromechanical resonators are experimentally analyzed in terms of the ΔE effect and signal-and-noise response, and models are developed and extended where necessary to identify current limitations. Although a large ΔE effect is confirmed in the shear modulus, the sensitivity of classical cantilever resonators does not benefit from this effect. An approach utilizing surface acoustic shear waves provides a solution and can detect small signals over a large bandwidth. Comprehensive analyses of the quality factor and piezoelectric material parameters indicate methods to increase sensitivity and signal-to-noise ratio significantly. The latter is currently limited by the loss of the magnetic material. First exchange-biased ΔE-effect sensors pave the way for compact setups and arrays with a large number of sensor elements. The insights gained lead to a new resonator and processing concept that can circumvent several previous limitations with prospects for sensor improvements in the future.

MA 9.4 Mon 16:05 H43

High-contrast mapping of atomic-scale spin-textures — •Lucas Schneider, Philip Beck, Jens Wiebe, and Roland Wiesendanger — Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

A scanning tunneling microscope (STM) with a magnetic tip that has a sufficiently strong spin polarization can be used to map the sample's spin structure down to the atomic scale [1] but usually lacks the possibility to absolutely determine the value of the sample's spin polarization. Magnetic impurities in superconducting materials give rise to pairs of perfectly, i.e., 100%, spin-polarized subgap resonances. In this talk, I will present a method exploiting this effect by functionalizing the apex of a superconducting Nb STM tip with such impurity states [2]. These tips can be used to probe the spin polarization of atom-manipulated Mn nanomagnets on a Nb(110) surface. By comparison with spin-polarized STM measurements of the same nanomagnets using conventional Cr bulk tips, we demonstrate an extraordinary spin sensitivity and the possibility to measure the sample's spin-polarization values close to the Fermi level quantitatively with the new functionalized probes.

[1] R. Wiesendanger, Rev. Mod. Phys. **81**, 1495 (2009)
[2] L. Schneider *et al.*, Sci. Adv. **7**, eabd7302 (2021)

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

MA 10: Non-Skyrmionic Magnetic Textures

Time: Monday 15:00–16:45 Location: H47

Invited Talk MA 10.1 Mon 15:00 H47

Magnetic vortices: into the third dimension — •Sebastian Gliga — Swiss Light Source, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland

Vortices are familiar phenomena in fluids and gases. In ferromagnets, they are naturally forming flux-closure states characterized by a curling of the magnetization around a very stable and narrow core. Over the past decades, vortex structures have been extensively studied in laterally confined thin-film elements owing to their rich dynamics [1]. Recently, non-destructive imaging of three-dimensional magnetic structures at the nanoscale has become possible. Using hard X-ray tomography [2], we have uncovered three-dimensional structures forming closed vortex loops in a bulk magnet. Based on magnetic vorticity (a quantity analogous to hydrodynamic vorticity), we identified these configurations as magnetic vortex rings [3]. In contrast to theoretical predictions, the observed vortex rings exist as static configurations, rather than purely dynamic states.
Our results open possibilities for further studies of complex three-dimensional solitons.

[1] R. Hertel, S. Gliga, M. Fähnle, and C. M. Schneider, Phys. Rev. Lett. **98**, 117201 (2007)
[2] C. Donnelly, M. Guizar-Sicairos, V. Scagnoli, S. Gliga, M. Holler, J. Raabe, L. J. Heyderman, Nature **547**, 328-331 (2017)
[3] C. Donnelly, K. L. Metlov, V. Scagnoli, M. Guizar-Sicairos, M. Holler, N. S. Bingham, J. Raabe, L. J. Heyderman, N. R. Cooper, S. Gliga, Nature Physics **17**, 316-321 (2021)

MA 10.2 Mon 15:30 H47

High-Resolution Magnetic Imaging of Surface Magnetic Textures in Synthetic Antiferromagnets Using SEMPA — •Mona Bhukta, Takaaki Dohi, M-A. Syskaki, Robert Frömter, and Mathias Kläui — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Magnetic skyrmions[1] are twisted spin configurations, which shows a non-zero skyrmion Hall angle when driven by current due to their topological nature[2], which is detrimental for applications. Skyrmions in synthetic antiferromagnet(SAFs), could suppress this effect owing to an overall zero topological charge. Recent observations of skyrmions in SAFs have opened the possibility for using skyrmions as a candidate for logic operations, data storage devices[3]. Here, we investigate different, more exotic spin textures in a SAF consisting of (CoFeB/Ir/CoFeB)n by using scanning electron microscopy with polarization analysis (SEMPA). The unique feature of SEMPA is especially effective on a SAFs enabling us to investigate the topological spin textures even in a fully compensated composition. We report high-resolved vortex-antivortex pairs in the SAF that are stable at zero magnetic fields and room temperature. Micromagnetic simulations of the investigated SAF stacks have been carried out to understand the way stabilize for these exotic spin textures as well as to explore the possible emergence of three-dimensional (3D) spin structures in the SAF multilayer system. [1] K. Everschor-Sitte et al., J. Appl. Phys. 124, 240901 (2018) [2] K. Litzius et al., Nat. Phys. 13, 170 (2017). [3] T. Dohi et al, Nat. Commun. 10, 5153 (2019).

MA 10.3 Mon 15:45 H47

Effects of static magnetic fields in antiferromagnetic ring-shaped spin chains — •Yelyzaveta A. Borysenko[1,2,3], Denis D. Sheka[1], Jürgen Fassbender[2], Jeroen van den Brink[3], Denys Makarov[2], and Oleksandr V. Pylypovskyi[2,4] — [1]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [2]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [3]IFW Dresden, Dresden, Germany — [4]Kyiv Academic University, Kyiv, Ukraine

While antiferromagnets with the easy axis of anisotropy are considered to be robust against external magnetic fields of a moderate strength, strong-field-driven spin reorientations provide an insight into subtle properties of the material usually hidden by the high symmetry of the ground state. Here, we address theoretically the effects of curvature in the curvilinear antiferromagnetic achiral anisotropic ring-shaped spin chains in strong magnetic fields. We identify the geometry-driven helimagnetic phase transition above the spin-flop field between the vortex and onion states. The spin-flop transition is of the first- or second-order depending on the ring curvature, which is influenced by the geometry-induced Dzyaloshinskii–Moriya interaction. Inhomogeneity of the Néel vector distribution in spin-flop phase generates weakly ferromagnetic response, which lies in the plane perpendicular to the applied magnetic field. Our findings provide an understanding of complex responses of curvilinear antiferromagnets on magnetic fields and allow further experimental study of geometrical effects relying on spin-chain-based nanomagnets.

MA 10.4 Mon 16:00 H47

Screw dislocations in chiral magnets — •Maria Azhar[1], Volodymyr Kravchuk[1,2], and Markus Garst[1] — [1]Karlsruhe Institute of Technology, Germany — [2]Bogolyubov Institute for Theoretical Physics of National Academy of Sciences of Ukraine, Kyiv, Ukraine

The Dyzaloshinskii-Moriya interaction stabilizes helimagnetic order in cubic chiral magnets for a large range of temperatures and applied magnetic field. In this helimagnetic phase the magnetization varies only along the helix axis, that is aligned with the applied field, giving rise to a one-dimensional periodic magnetic texture. This texture shares many similarities with generic lamellar order like cholesteric liquid crystals, for example, it possesses disclination and dislocation defects [1]. Here, we investigate both analytically and numerically screw dislocations of helimagnetic order. Whereas the far-field of these defects is universal, we find that various core structures can be realized even for the same Burgers vector of the screw dislocation. In particular, we identify screw dislocations with smooth magnetic core structures, that close to the transition to the field-polarized phase continuously connect either to vortices of the XY-order parameter or to skyrmion strings. In addition, close to zero fields we find singular core structure comprising a chain of Bloch points with alternating topological charge [2].

[1] P. Schoenherr et al. Nature Physics 14, 465 (2018).
[2] M. Azhar, V. Kravchuk, and M. Garst, Physical Review Letters 128, 157204 (2022).

MA 10.5 Mon 16:15 H47

Chiral response of spin spiral states as the origin of chiral transport fingerprints of spin textures — •Jonathan Kipp[1,2], Fabian Lux[3], and Yuriy Mokrousov[2,3] — [1]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [2]Peter Gr\"unberg Institut and Institute for Advanced Simulation, Forschungszentrum J\"ulich and JARA, 52425 J\"ulich, Germany — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

To extend the commonly accepted yet simplifying and approximate picture of transport effects taking place in systems with spatially varying magnetization such as skyrmions, domain walls and multi-q states, it is important to understand the transport properties of the homochiral spin-spiral states, which are building blocks for these more advanced textures of different nature and dimensionality. In this work, by referring to phenomenological symmetry arguments based on gradient expansion and explicit calculations within the Kubo framework, we study transport properties of various types of spin-spirals in a two-dimensional model with strong spin-orbit interaction. Specifically, we focus on the contributions to the magnetoconductivity, planar Hall effect and anomalous Hall effect, which are sensitive to the sense of chirality of the spiral states. In particular, we analyze the emergence, symmetry, and microscopic properties of the resulting chiral magnetoconductivity, chiral planar Hall effect and chiral Hall effect in terms of spin-spiral propagation direction, cone angle, spiral pitch and disorder strength.

MA 10.6 Mon 16:30 H47

Single-crystal growth and low temperature properties of ErB_2 — •Christoph Resch[1], Andreas Bauer[1], Georg Benka[2], and Christian Pfleiderer[1] — [1]TU München Physik-Department, 85748 Garching, Germany — [2]Kiutra GmbH, 81369 München, Germany

Single crystals of the hexagonal rare-earth diboride ErB_2 were synthesized by means of the self-adjusted flux travelling solvent optical floating zone technique and metallurgically characterized. The magnetic phase diagram of single crystalline ErB_2 was inferred from measurements of the specific heat, the magnetisation, the ac susceptibility, and the electrical transport for fields applied along major crystallographic axes. We find behavior characteristic of an easy-plane antiferromagnet below $T_N = 14$ K. For magnetic fields applied along the hard out-of-plane axis we observe a spin-flip transition at $B_N = 12$ T. Most notably, the Hall resistivity below T_N for fields applied along the hard axis exhibits a large anomalous contribution that does not scale with the uniform magnetization. Possible origins include spin-chirality mechanisms and large Berry curvatures associated with a canted spin structure, or more exotic types of magnetic order.

MA 11: Computational Magnetism 1

Time: Monday 15:00–17:00 Location: H48

MA 11.1 Mon 15:00 H48

Monte Carlo modeling of magnetic crystals from graphical input — Michael Giger, •Amadé Bortis, Manfred Fiebig, and Thomas Lottermoser — Department of Materials, ETH Zurich

Magnetism in crystals can be described by a spin Hamiltonian which contains all the magnetic interactions between spins. The resulting magnetic properties of the material, like the spin-ordering or the critical behavior, can be derived from Monte Carlo simulations. The correct and efficient implementation of such a Hamiltonian into a computer program for the simulation is error-prone and time-consuming. Here, we present a tool where the magnetic interactions can be defined by connecting atoms in a three-dimensional visualization of a crystal. Our software then automatically generates an efficient code for the Monte Carlo simulations. All simulation parameters can be set in a graphical user interface. We will showcase our software by reproducing the magnetic order in the prototypical antiferromagnet Cr_2O_3 as an example. Our tool thus makes Monte Carlo simulations of complex spin systems more accessible to non-specialist users.

MA 11.2 Mon 15:15 H48

AiiDA-UppASD: Automatic workflow engine for high-throughput mag-netic simulations and machine learning — •Qichen Xu[1,2,3], Jonathan Chico[4], Manuel Pereiro[2], Danny Thonig[5], Erik Sjöqvist[2], Olle Eriksson[2], Anders Bergman[2], and Anna Delin[1,3] — [1]KTH Royal Institute of Technology, Stockholm,Sweden — [2]Uppsala University, Uppsala, Sweden — [3]Swedish e-Science Research Center, Stockholm,Sweden — [4]Sandvik Coromant, Stockholm, Sweden — [5]Örebro University,Örebro,Sweden

The ever-raising theoretical peak performance and accessibility of supercomputer resources bring automated simulations to a more important position for studies of magnetic materials properties. Recently, Huber et al. developed the AiiDA framework. In order to perform high-throughput atomic spin dynamics (ASD) simulations and take advantage of AiiDA platform and its build-in DFT plugins, we introduce the AiiDA-UppASD plugin which allows users to access to the majority of the functionalities of the UppASD code within the AiiDA framework via a Python package. In addition, several robust built-in workflows are also provided for managing ASD simulations, handling possible errors, and providing common modular workchains. With these workflows, complex tasks like high-throughput simulations of magnetodynamic properties as well as the determination of spin-wave excitation spectra and magnetic phase diagrams can be performed in a very efficient manner. Meanwhile, a machine learning (ML) prepared data generation workflow is also designed in order to offer ASD-related databases for the ML community to benchmark and develop methods.

MA 11.3 Mon 15:30 H48

Calculation of magnetic properties using Green's functions in the LAPW basis — •Henning Janssen[1,2], Stefan Blügel[1], Gustav Bihlmayer[1], and Alexander Shick[3] — [1]Forschungszentrum Jülich, Jülich, Germany — [2]RWTH, Aachen, Germany — [3]Czech Academy of Sciences, Prague, Czech Republic

Green's functions are a powerful tool for understanding responses and interactions, including the magnetic properties, in materials.

A method for calculating Green's functions utilizing the Kramers-Kronig transformation is presented. The implementation of this method in the linearized augmented plane-wave basis, as implemented in the Fleur code [1], is especially suited for orbitals mainly localized inside the Muffin-tin regions around the atoms. These Green's functions are used to calculate magnetic properties including the Heisenberg exchange constants J_{ij} or the Dzyaloshinskii-Moriya Interaction (DMI) using force-theorem methods [2] and non-collinear torques. Results for these calculations are shown for bulk systems of iron and Co/Pt films.

The authors gratefully acknowledge the computing time granted by the JARA Vergabegremium and provided on the JARA Partition part of the supercomputer CLAIX at RWTH Aachen University.

[1]: www.flapw.de
[2]: A. I. Liechtenstein, et al. J. Magn. Magn. Mater. **67**, 65 (1987)

MA 11.4 Mon 15:45 H48

Ab initio study of exchange interactions at planar defects of crystal lattices — •Martin Zelený[1], Monika Všianská[2], Denis Ledue[3], Renaud Patte[3], Miroslav Černý[4], Ladislav Straka[5], and Oleg Heczko[5] — [1]Institute of Materials Science and Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic — [2]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic — [3]Normandie Université, UNIROUEN, INSA Rouen, CNRS, GPM, Saint Étienne du Rouvray, France — [4]Central European Institute of Technology, Brno University of Technology, Czech Republic — [5]FZU - Institute of Physics of the Czech Academy of Sciences, Czech Republic

Planar defects play an important role in crystalline magnetic materials, because they serve as obstacles to magnetic domain wall motion. Atomistic description of the magnetic properties requires knowledge of exchange interaction parameters J_{ij} between two atomic sites. These parameters can be found in literature for many bulk magnetic materials. However, very little is known about J_{ij} in the vicinity of planar defects where the symmetry of crystal lattice is reduced and atoms have different chemical environment. We provide deep analysis of J_{ij} obtained from ab initio calculations in the vicinity of the clean $\Sigma5(310)$ grain boundary in bcc Fe as well as grain boundary with segregated P impurities. We analyze also J_{ij} parameters in the vicinity of twin boundaries and antiphase boundaries in Ni_2MnGa magnetic shape memory alloys. Our results show strong influence of planar defects on exchange interactions.

MA 11.5 Mon 16:00 H48

Computationally Driven Evaluation of Magnetocrystalline Anisotropy — •Simone Köcher[1,2] and Stefano Sanvito[1] — [1]School of Physics / CRANN, Trinity College Dublin, Ireland — [2]IEK-9 - Fundamental Electrochemistry, Forschungszentrum Jülich, Germany

Custom-tailored magnetic materials are a crucial component in numerous modern technologies. The experimental search for new high-performance magnets can profit considerably from guidance by computational screening approaches, which however depend on reliable first-principle methods for calculating the key physical properties which underlie the magnetism of the material. One of them is the magnetocrystalline anisotropy (MCA), which contributes to the magnetic hardness.

For the well-studied $X(acac)_3$ (X = transition metal) coordination complexes we specifically explore and compare different methods for calculating the MCA: the finite energy difference approach (force theorem) within periodic boundary conditions and all-electron, full-potential perturbative approaches ranging from PT2 on PBE DFT to CASSCF-PT2 and NEVPT2. We explicitly study the influence of cluster geometry and various computational parameters at different levels of theory. Finally, we address the challenges involved in high-throughput MCA calculations for material screening applications.

MA 11.6 Mon 16:15 H48

Functional RG for Rydberg Array Spin Hamiltonians — •Benedikt Schneider — Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig Maximilian University Munich, 80333, Germany

Rydberg-Atom arrays are a versatile platform to simulate strongly correlated phenomena from spin liquids to lattice gauge theories. We develop a functional renormalization group approach based on Kitaev's pseudo-Majorana spin representation that produces quantitative accurate results for Rydberg array Hamiltonians at finite temperature. A special feature of our approach is that implementation of infinite lattices with long-range interactions and complicated lattice geometries is straightforward.

MA 11.7 Mon 16:30 H48

Hubbard interactions in 2D magnetic $FePS_3$ and CrI_3 — •Fatemeh Haddadi[1], Edward Linscott[1], Marco Gibertini[2], Iurii Timrov[1], and Nicola Marzari[1] — [1]THEOS and MARVELL, EPFL, Lausanne, Switzerland — [2]University of Modena and Reggio Emilia, Modena, Italy

Hubbard-corrected density-functional theory has proven to be successful in addressing self-interaction errors in 3D magnetic materials. However, the effectiveness of this approach for magnetic 2D materials has remained elusive. Here, we use PBEsol+U and its extensions to investigate the electronic, structural, and vibrational properties of two 2D magnets: antiferromagnetic $FePS_3$ and ferromagnetic CrI_3. Hubbard parameters are computed from first-principles using density-functional perturbation theory (DFPT) [PRB 98, 085127 (2018)], thus avoiding any empiricism. First, we show that for $FePS_3$ the Hubbard corrections are crucial for obtaining the experimentally observed insulating state with the correct crystal symmetry. While empirical U can lead to instabilities, the Hubbard parameters from DFPT stabilize the ground state. We show that Hubbard-corrected vibrational frequencies are in good agreement with Raman experiments. Finally, we discuss 2D CrI_3, and the requirements it elicits in correcting separately the majority and minority bands.

MA 11.8 Mon 16:45 H48

Magnetism in strongly correlated twisted bilayers from first principles — •Aditya Putatunda and Sergey Artyukhin — Italian Institute of Technology, Genova, Italy

Twisted bilayer structures of van der Waals materials attract experimental and theoretical interest because of easy single layer exfoliation and processing and a variety of correlated states.1,2 Magnetic twisted bilayers hosting skyrmions have recently been demonstrated.3 Within first-principles approach, large supercells and tight convergence are required to compute magnetic interactions. Here we combine DFT and model simulations of Wannier function based tight-binding Hamiltonian to study the states in the twisted bilayer of CrI3.

[1] Xu et al., Nature Nanotechnology 17, 143*147 (2022) [2] N. Sivadas., Nano Lett. 18, 7658*7664 (2018) [3] Shang et al., ACS Appl. Nano Mater. 3, 1282*1288 (2020)

MA 12: Skyrmions 1 (joint session MA/KFM)

Time: Tuesday 9:30–12:45 Location: H37

Invited Talk MA 12.1 Tue 9:30 H37

Topological spin structures at surfaces — •Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany

Magnetic skyrmions are of great interest for future applications ranging from data storage to neuromorphic computing [1]. Fundamental insight into the properties of skyrmions and the underlying microscopic interactions can be obtained by studying them at surfaces [2,3]. Here, I will discuss the stabilization, creation, and annihilation mechanisms of nanoscale topological spin structures based on density functional theory and atomistic spin simulations [4-8]. A novel skyrmion annihilation mechanism, the Chimera collapse [4], is presented which has been confirmed by direct comparison with scanning tunneling microscopy (STM) experiments [5]. It is further shown that skyrmion stability can be tuned via applied electric fields [6] allowing writing and deleting of skyrmions. Higher-order exchange interactions (HOI) beyond Heisenberg exchange also play a role since they can stabilize skyrmion lattices [2] as well as isolated skyrmions or antiskyrmions [7]. Unexpectedly, HOI can induce not only non-collinear but also collinear two-dimensional multi-Q states observed via spin-polarized STM [8].

[1] A. Fert *et al.*, Nat. Rev. Mater. **2**, 1 (2017), [2] S. Heinze *et al.*, Nat. Phys. **7**, 713 (2011), [3] N. Romming *et al.*, Science **341**, 639 (2013), [4] S. Meyer *et al.*, Nat. Commun. **10**, 3823 (2019), [5] F. Muckel *et al.*, Nat. Phys. **17**, 395 (2021), [6] S. Paul *et al.*, npj Comput. Mater. **8**, 105 (2022), [7] S. Paul *et al.*, Nat. Commun. **11**, 4756 (2020), [8] M. Gutzeit *et al.*, arxiv:2204.01358 (2022).

MA 12.2 Tue 10:00 H37

Controlling Magnetic Skyrmion Nucleation and Motion — •Lisa-Marie Kern[1], Victor Deinhart[1,4], Kathinka Gerlinger[1], Michael Schneider[1], Dieter Engel[1], Christian Günther[2,3], Katja Höflich[4,5], Riccardo Batistelli[4], Daniel Metternich[4], Felix Büttner[4], Bastian Pfau[1], and Stefan Eisebitt[1,3] — [1]Max-Born-Institut, Berlin, Germany — [2]Zentraleinrichtung für Elektronenmikroskopie (ZELMI), Technische Universität, Berlin, Germany — [3]Institut für Optik und Atomare Physik, Technische Universität, Berlin, Germany — [4]Helmholtz Zentrum für Materialien und Energie, Berlin, Germany — [5]Ferdinand-Braun-Institut, Berlin, Germany

Magnetic skyrmions are topological quasiparticles, stabilized in out-of-plane magnetized multilayers. Great advances have been reported in generating, annihilating and shifting skyrmions via spin-orbit torque from spin-polarized currents. Optical nucleation with single laser pulses offers a possibly faster and more energy-efficient alternative. While the underlying mechanisms of the nucleation are different, both methods suffer from a certain stochasticity in the spatial distribution of the skyrmions nucleated. However, in view of scientific and practical applications, a controllable localization of the skyrmion's nucleation site is typically required. Nanopatterning of a tailored magnetic anisotropy landscape using He+-ions provides a promising platform for enhanced control of skyrmions in thin films. Based on this technique, we have recently demonstrated reproducible skyrmion nucleation and motion - a prerequisite for any fundamental or applied research on topological structures.

MA 12.3 Tue 10:15 H37

Current-Induced H-Shaped Skyrmion Creation and Their Dynamics in the Helical Phase — •Ross Knapman[1,4], Davi R Rodrigues[2], Jan Masell[3], and Karin Everschor-Sitte[4,5] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Department of Electrical and Information Engineering, Politecnico di Bari, 70126 Bari, Italy — [3]RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan — [4]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany — [5]Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, 47057 Duisburg, Germany

A potential application of magnetic skyrmions is in racetrack memory devices. [1] While efforts have often been concentrated on the use of ferromagnetic and antiferromagnetic racetracks, previous work has suggested that the use of helimagnets could be more effective. [2] Here, the helices provide a means to naturally confine the skyrmions to quasi-1D channels, mitigating the skyrmion Hall effect. They additionally allow for high-speed skyrmion motion. Moreover, inspired by previous works which demonstrated electric-current-controlled skyrmion injection at magnetic impurities, [3] we propose a method of creating skyrmions in a helical background. [4]

[1] Fert, A. et. al., Nat. Nanotechnol. **8**, 152-156 (2013)
[2] Müller, J. et. al., Phys. Rev. Lett. **119**, 137201 (2017)
[3] Everschor-Sitte, K. et. al., New J. Phys. **19**, 092001 (2017)
[4] **Knapman, R.** et. al. J. Phys. D: Appl. Phys. **54**, 404003 (2021)

MA 12.4 Tue 10:30 H37

Skyrmion automotion in confined geometries for applications — •Kilian Leutner[1], Thomas Brian Winkler[1], Hans Fangohr[2,3], and Mathias Kläui[1] — [1]Johannes Gutenberg University, Institute for Physics, Staudinger Weg 7, 55128 Mainz, Germany — [2]Max-Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany. — [3]University of Southampton, SO17 1BJ, Southampton, United Kingdom

Magnetic skyrmions are promising candidates for energy-efficient applications due to their quasi-particle nature and their topological stabilization. We present here a new concept for a multi-turn sensor-counter based on skyrmions. The skyrmion-boundary force in confined geometries leads with the topology-dependent dynamics to the effect of automotion in certain cases. Automotion describes the movement of magnetic structures without the supply of external energy. For our case, we describe and investigate this effect with micromagnetic simulations and the coarse-grained Thiele equation. Automotion has already been demonstrated for domain walls [1], but is not well explored in skyrmionic systems yet.

[1] M.-A. Mawass et al, Phys. Rev. Applied 7, 044009, 2017

MA 12.5 Tue 10:45 H37

Walking Skyrmions — •Alla Bezvershenko and Achim Rosch — Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany

We study the pinning - unpinning transition of the skyrmion lattice in bulk MnSi under applying a slowly oscillating transverse magnetic field. We model the system using an elastic model for skyrmion strings in the presence of pinning forces. With this effective model we show that the presence of a transverse magnetic field reduces the critical current density needed to depin the skyrmion lattice, reaching zero at the critical magnetic field value. Further, the complete phase diagram of this model will be discussed. Below the threshold amplitude, the skyrmion lines stay fully pinned. Upon increasing the amplitude, a so-called "walking" phase starts, where the skyrmion lines start to unpin. If in this phase a sufficiently large electric current is being applied, the skyrmion lattice starts to move. Obtained results are compared to the experimental data on the transverse susceptibility measurements for this system.

MA 12.6 Tue 11:00 H37

Small-angle neutron scattering of kinetically driven skyrmion lattice motion — •Denis Mettus[1], Alfonso Chacon[1], Andreas Bauer[1], Sebastian Mülbauer[2], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany

Skyrmions are topologically non-trivial spin textures that exhibit an exceptionally efficient coupling to spin currents, notably spin-polarized charge currents and magnon currents as observed in MnSi, FeGe, and Cu_2OSeO_3. This raises the question for the microscopic mechanisms that control the pinning of the skyrmion lattice, and how they depend on the topology, electronic structure, and disorder. We report neutron scattering measurements of kinetically driven skyrmion lattice unpinning and motion by means of Time-Involved Small Angle Neutron scattering Experiment (TISANE). In our study we examined the unpinning process under changing field orientation for different materials including the metallic systems $Mn_{1-x}Fe_xSi$ and the insulator Cu_2OSeO_3. We discuss our results in the light of methodological aspects of the TISANE technique and recent theoretical predictions of walking skyrmions.

MA 12.7 Tue 11:15 H37

Spin Wave Driven Skyrmions in Antiferromagnets — •Michael Lau[1], Wolfgang Häusler[2], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]Institute of Physics, University of Augsburg

In a two-dimensional lattice of antiferromagnetically coupled classical magnetic moments of unit length it is theoretically possible to stabilize Skyrmions when appropriately adjusting the Dzyaloshinskii-Moriya interaction (DMI) and a uniaxial anisotropy. We present simulations on a discrete lattice which reveal that these Skyrmions can be moved by spin waves injected at one edge of the lattice. It is known that in ferromagnets spin waves are scattered by Skyrmions, imposing a driving force on them. In antiferromagnets, we find similar scattering of spin waves by Skyrmions, exerting a net driving force. However, contrary to ferromagnets, the driving force acts in the direction of spin wave propagation and the Skyrmion accelerates like a classical particle with finite mass, as typically found for antiferromagnetic solitons. Additionally, we exploit the fact that antiferromagnetic spin waves can appear left- or right handed and study the impact of spin waves of different polarizations on the Skyrmion. It turns out that chirality, frequency and amplitude of the spin waves all significantly influence the Skyrmion motion.

MA 12.8 Tue 11:30 H37

Skyrmion lattice dynamics — •Daniel Schick, Markus Weissenhofer, Levente Rózsa, and Ulrich Nowak — Universität Konstanz, Konstanz, Germany

We investigate the movement of skyrmions in lattices by performing molecular dynamics simulations based on the Thiele equation [1], using different effective skyrmion-skyrmion interactions. We compare mean-square displacement and the dynamical orientational correlation function $g_6(t)$ for different values of damping α and different topological charges and find the topological charge to change the effect of damping on the examined quantities. Furthermore, we find that for finite topological charge, the mean-square displacement in low-density skyrmion lattices increases compared to free diffusion. By comparing to trivial topology, we can demonstrate the increase in mean-square displacement to be the result of the gyrocoupling of skyrmions.

[1] A.A. Thiele, Phys. Rev. Lett. 30, 6 (1973)

MA 12.9 Tue 11:45 H37

Skyrmion Pinning Energetics in Thin Film Systems — Raphael Gruber[1], Jakub Zázvorka[1], •Maarten A. Brems[1], Davi R. Rodrigues[1], Takaaki Dohi[1], Nico Kerber[1], Boris Seng[1], Mehran Vafaee-Khanjani[1], Karin Everschor-Sitte[2], Peter Virnau[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany

Magnetic skyrmions in thin films have been shown to exhibit thermal diffusion, making them a promising system for applications in probabilistic computing [1] as well as Brownian computing [2]. In such applications, pinning effects are of crucial importance as the pinning strength is often comparable to thermal excitations and thus impacts the operation of skyrmion-based devices. Using thermal skyrmion dynamics, we characterize the pinning in a sample and ascertain the spatially resolved energy landscape [3]. To understand the mechanism of pinning, we image the skyrmion pinning details and find a strong size-dependence. We observe that the skyrmion is pinned at its boundary (domain wall) and not as previously considered at its core. As a consequence, we find that the size-dependence follows from different favorable overlaps of the skyrmion boundary with the pinning regions, which is supported by micromagnetic simulations. This allows us to switch pinning sites on and off by small tuning of external fields. [1] J. Zázvorka et al., Nat. Nanotechnol. 14, 658 (2019). [2] M. A. Brems et al., Appl. Phys. Lett. 119, 132405 (2021). [3] R. Gruber et al., under review (2021).

MA 12.10 Tue 12:00 H37

Coexistence of topologically distinct spin textures — •Börge Göbel[1], Jagannath Jena[2], Stuart Parkin[2], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle

Over the last decade, the field of skyrmionics has attracted great research interest, as skyrmions (small, whirl-like spin textures) possess a topologically-induced stability that allows to consider them as the carriers of information in future data storage devices. However, due to their integer topological charge there are two major shortcomings of skyrmion-based racetrack storages: The skyrmions do not move parallel to a current and multiple skyrmions attract and repell each other.

A solution to these problems is the utilization of alternative magnetic nano-objects that go beyond conventional skyrmions; see review [1]. In this talk, we show via simulations, Lorentz transmission electron microscopy measurements [2,3] and Hall transport measurements [4] that skyrmions, antiskyrmion and topologically trivial bubbles [5] can coexist in Heusler materials. They can even appear fractionally near the sample's edges [6]. We propose an advanced version of the racetrack storage device based on these results.

[1] BG et al. Physics Reports 895, 1-28 (2021), [2] Jena, BG et al. Nat. Com. 11, 1115 (2020), [3] Jena, BG et al. Science Advances 6, eabc0723 (2020), [4] Sivakumar, BG et al. ACS Nano 14, 13463 (2020), [5] BG et al. PRAppl. 15, 064052 (2021), [6] Jena, BG et al. Nat. Com. 13, 2348 (2022)

MA 12.11 Tue 12:15 H37

Topological magnetism in multiferroic lacunar spinels — •Vladislav Borisov[1], Patrik Thunström[1], Anna Delin[2], and Olle Eriksson[1,3] — [1]Ångström Laboratory, Uppsala University, Uppsala, Sweden — [2]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden — [3]Örebro University, Örebro, Sweden

Several skyrmionic magnetic systems have been discovered since the first observation of skyrmions in a B20 compound MnSi. Only a few of them host not just magnetism but also ferroelectricity and prominent examples are lacunar spinels GaV_4S_8 and GaV_4Se_8. These bulk systems are rather unique, because they host Neel skyrmions, which are otherwise only observed in metallic multilayers. Detailed description of magnetic phenomena in the multiferroic spinels is challenging for theory due to correlations within the V_4 clusters.

We study the role of the magnetic state of these clusters and electronic correlations for the Heisenberg and Dzyaloshinskii-Moriya interactions in V- and Mo-based lacunar spinels. The character of magnetic interactions is discussed in relation to the crystal symmetry and electronic properties derived from the V_4 molecular orbitals. Based on micromagnetic simulations, we determine the role of different interactions for the formation of magnetic textures.

This work was supported by the Knut and Alice Wallenberg Foundation, the Swedish Research Council and the Swedish National Infrastructure for Computing.

MA 12.12 Tue 12:30 H37

Systematic identification and assessment of topological spin textures via saddle point searches — •Hendrik Schrautzer[1,2], Grzegorz Kwiatkowski[1], Hannes Jónsson[1], Pavel F. Bessarab[1,3], and Stefan Heinze[2] — [1]University of Iceland, Reykjavik, Iceland — [2]Christian-Albrechts-University, Kiel, Germany — [3]Linnaeus University, Kalmar, Sweden

Magnetic systems hosting topological textures such as skyrmions have been of great technological and fundamental interest in recent years. The growing zoo [1] of co-existing meta-stable states makes investigation of such systems challenging. Here, we present a methodology combining global optimization based on recursive traversing between energy minima via saddle points on the energy surface [2,3], and harmonic transition state theory. The methodology provides a systematic approach to predict previously unknown metastable states, identify their lifetime at a given temperature and compute kinetics of their mutual transformations. We apply the method to the widely studied Pd/Fe/Ir(111) skyrmionic system, parametrized using density functional theory, and predict a variety of new transition mechanisms and spin textures including skyrmions with chiral kinks [1], which have been unknown so far in this system.

1: V. M. Kuchkin, *et al.*, Phys. Rev. B **102**.14 (2020): 144422.
2: A. Pedersen, *et al.*, International Workshop on Applied Parallel Computing (pp. 34-44) (2010). Springer, Berlin, Heidelberg.
3: G. P. Müller *et al.*, Phys. Rev. Lett. **121**.19 (2018): 197202

MA 13: Magnonics 1

Time: Tuesday 9:30–12:30 Location: H43

MA 13.1 Tue 9:30 H43

Topology induced spin-wave modes in curved surfaces — •Michael Vogel[1], Tim Mewes[2], and Claudia Mewes[2] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany — [2]Department of Physics and Astronomy, University of Alabama, Tuscaloosa, USA

Extending the research of magnetization dynamics from planar two-dimensional structures into the third dimension [1] promises rich physics from theoretically predicted fast domain wall velocities beyond the walker breakdown [2] to Cherenkov-like effects for magnons[3]. Here we investigate the effects of curvature in soft-magnetic hemispheres by means of micromagnetic simulation. The resonant spin-wave spectrum is calculated for different geometries and the power-spectral density is evaluated. The interplay of the local curvature and the external field gives rise to new spin-wave modes at relatively high frequencies located a the edge of the three-dimensional objects.

1. R. Kandori et al., J. Phys. D Appl. Phys. J. Phys. D Appl. Phys. 49, 45 (2016). 2. M. Yan, A. Kákay, S. Gliga, R. Hertel, Phys. Rev. Lett. 104, 057201 (2010). 3. M. Yan, A. Kákay, C. Andreas, R. Hertel, Phys. Rev. B - Condens. Matter Mater. Phys. 88, 20412 (2013).

MA 13.2 Tue 9:45 H43

Propagating Spin-Wave Spectroscopy Studies in a Millikelvin Temperature Environment — •David Schmoll, Sebastian Knauer, Rostyslav Serha, Qi Wang, and Andrii Chumak — University of Vienna, Faculty of Physics, Boltzmanngasse 5, A-1090 Vienna, Austria

Technological advancements in the access to millikelvin temperatures, combined with high-frequency microwave technology, allow first steps towards the investigation of individual magnons, as the corresponding quasi-particles of spin waves, in the field of quantum magnonics. Such experiments require millikelvin base temperatures, to ensure a thermal magnon-free system. We measured spin-wave propagation for external bias magnetic fields in the range of 300 mT to -300 mT at room temperature and at a base temperature of 45 mK. The results were obtained in a cryogenic propagating spin-wave spectroscopy setup, comprising a dilution refrigerator, a 9-1-1 T vector magnet, and a 65 GHz-rated VNA measurement system. The spin-wave transmission was measured in a 70 mm × 2 mm × 5.65 μm yttrium-iron-garnet (YIG) film on a 500 μm-thick gadolinium-gallium-garnet (GGG) substrate in the Magnetostatic Surface Spin-Wave Configuration (MSSW), using a microstrip antenna PCB. The demonstration of spin-wave propagation at cryogenic temperatures, provides the technical capabilities and the platform for future investigations of individual magnons. Moreover, direct optical access to the dilution refrigerator allows millikelvin experiments in the field of hybrid opto-magnonic quantum systems.

MA 13.3 Tue 10:00 H43

Finite-element micromagnetic modeling of spin-wave propagation with the open-source package TetraX — •Lukas Körber[1,2], Gwendolyn Quasebarth[1,2], Alexander Hempel[1,2], Andreas Otto[2], Jürgen Fassbender[1,2], and Attila Kákay[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Dresden Germany — [2]Fakultät Physik, Technische Universität Dresden

We present a finite-element-method (FEM) dynamic-matrix approach to efficiently calculate the dispersion and spatial mode profiles of spin waves propagating in waveguides with arbitrary cross section, where the equilibrium magnetization is invariant along the propagation direction. This is achieved by solving numerically a linearized version of the equation of motion of the magnetization only in a single cross section of the waveguide at hand. To compute the dipolar field, we present an extension of the well-known Fredkin-Koehler method to plane waves. The presented dynamic-matrix approach is implemented within our recently published open-source micromagnetic modeling package TetraX [1] which aims to provide user friendly and versatile FEM workflows for the magnonics community (not only for magnonics community, but FEM simulations in general), covering several classes of sample geometries and, in the near future, also antiferromagnets. As a brief introduction, this talk will include a short live-demo of TetraX.

[1] https://gitlab.hzdr.de/micromagnetic-modeling/tetrax

MA 13.4 Tue 10:15 H43

Magnons in antiferromagnets: tools for transport and processing of information — •Olena Gomonay — 1Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany

Magnonics as a concept of information processing with magnon spins is a promising alternative to spintronics, which manipulates electron-mediated spin currents. Magnons in antiferromagnets have further advantages of high limiting velocities and long propagation length compared to their ferromagnetic counterparts. Moreover, magnon currents in antiferromagnets, in contrast to ferromagnets, can carry both spin orientations and thus can be used for manipulation of the magnetic states. In my talk I discuss different aspects of magnon-mediated transport in antiferromagnets and possible applications to information processing. I compare two mechanisms of the nonlocal spin transport observed in easy-plane and easy-axis antiferromagnets via spin-polarised eigenmodes and via magnon birefringence. Magnon birefringence effect can be also observed in the multidomain antiferromagnets with the pronounced magnetostriction. Interaction of magnons in such a case results in a paramagnetic downconversion and resonance excitation of different magnon modes. I show further how the spin-polarised magnons can be used for manipulation of the magnetic states in multilayered films.

MA 13.5 Tue 10:30 H43

A bifold theoretical approach to spin transport in 2D easy axis and easy plane antiferromagnets — •Verena Brehm and

Alireza Qaiumzadeh — QuSpin, NTNU Trondheim, Norway

Due to their terahertz excitation spectrum and the absence of stray fields, antiferromagnetic insulators are great candidates for magnonic applications [1].

We model an antiferromagnet with homogenous DMI inspired by hematite α-Fe_2O_3, that undergoes two phase transitions: For very low temperatures, there is no magnetization as the Néel vector lies in the plane, which corresponds to an easy axis anisotropy. At the Morin temperature, the Néel vector rotates out of plane, leading to a finite DMI-induced magnetization with the system being in an easy plane phase, until at the Néel temperature magnetic order is lost. Spin transport measurements across the Morin temperature [2] are exciting, since the magnonic modes show an anisotropy-dependent polarization [3], which has an impact on the transported angular momentum [4].

In this talk, we demonstrate both analytically and numerically (micromagnetic simulations [5]), how the magnon polarization impacts the spin transport signal across the Morin transition, in connection to Néel vector dynamics and dispersion relation analysis.

[1] Rezende, White. *Phys. Rev. B* **14** (1976)
[2] Ross et al. *J. Mag. Magn. Mat.* **453** (2022); arXiv:2106.12853
[3] Rezende et al. *J. Appl. Phys.* **126** (2019)
[4] Lebrun, Kl¨aui et al. *Nat. Comm.* **11** 6332 (2020)
[5] Lepadatu. *J. Appl. Phys.* **128** 243902 (2020)

MA 13.6 Tue 10:45 H43

Employing magnons for generating multi-qubit entangled states for quantum error correction — Ida Skogvoll[1], Jonas Lidal[1], Jeroen Danon[1], and •Akashdeep Kamra[2,1] — [1]Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway — [2]Condensed Matter Physics Center (IFIMAC) and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain

The ongoing rapid progress towards quantum technologies relies on new hybrid platforms optimized for specific quantum computation and communication tasks, and researchers are striving to achieve such platforms. We study theoretically a spin qubit exchange-coupled to an anisotropic ferromagnet that hosts magnons with a controllable degree of intrinsic squeezing. We find this system to physically realize the quantum Rabi model from the isotropic to the Jaynes-Cummings limit with coupling strengths that can reach the deep-strong regime. We demonstrate that the composite nature of the squeezed magnon enables concurrent excitation of three spin qubits coupled to the same magnet. Thus, three-qubit Greenberger-Horne-Zeilinger and related states needed for implementing Shor's quantum error-correction code can be robustly generated. Our analysis highlights some unique advantages offered by this hybrid platform, and we hope that it will motivate corresponding experimental efforts.

I. C. Skogvoll, J. Lidal, J. Danon, and A. Kamra, Phys. Rev. Applied 16, 064008 (2021).

MA 13.7 Tue 11:00 H43

Long-range quantum entanglement between two distant ferromagnets mediated by dipol-dipol interaction — •Dennis Wuhrer, Niklas Rohling, and Wolfgang Belzig — Universität Konstanz, D-78457 Konstanz, Germany

Recently the quantum states of an antiferromagnet in the spin wave approximation have been identified as two-mode squeezed sublattice-magnon states. The massive sublattice entanglement leads to a nontrivial structure of the two-mode squeezed vacuum in the magnetic Brillouin Zone.

Further the entanglement in synthetic antiferromagnets became of interest. It can be tuned by an applied magnetic field, but an extraction of squeezing parameters is difficult. In this talk we regard a system consisting of two distant 2D ferromagnets coupled via dipol-dipol interaction. The Bogoliubov transformation will be interpreted in terms of inter-/intra-layer squeezing and hybridisation parameters. Using the logarithmic negativity we derive an analytic formula to quantify the degree of entanglement for which we investigate the distance dependence due to the long-range interaction. Using the distance and an external field the entanglement can be manipulated from zero to large values and maintained over large distances. The prospect to transfer massive entanglement over large distances is discussed.

MA 13.8 Tue 11:15 H43

Control of the Magnon Bose-Einstein Condensation by the Spin Hall Effect — •Michael Schneider[1], David Breitbach[1], Alexander A. Serga[1], Andrei N. Slavin[2], Vasyl S. Tyberkevich[2], Björn Heinz[1], Bert Lägel[1], Carsten Dubs[3], Philipp Pirro[1], Burkard Hillebrands[1], and Andrii V. Chumak[4] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany — [2]Department of Physics, Oakland University, Rochester, Michigan 48326, USA — [3]INNOVENT e.V. Technologieentwicklung, D-07745 Jena, Germany — [4]Faculty of Physics, University of Vienna, A-1090 Vienna, Austria

Generally, magnon Bose-Einstein condensation (BEC) is achieved by increasing the particle density. Previously, it was shown that the rapid cooling of yttrium-iron garnet/Pt nanostructures, preheated by an electric current passed through the Pt layer, leads to an imbalance between the magnon and the phonon system. Consequently, magnon BEC is triggered by the excess of magnons.

We report on the additional contribution of the spin Hall effect (SHE), generating a spin current in the Pt layer. Depending on the orientation of the electric current and the applied field, the SHE injects or annihilates magnons. We find that the SHE contribution prevents or promotes the rapid-cooling induced magnon BEC, changing the BEC threshold by -8% to +6% depending on the current polarity. These results demonstrate a new method for controlling macroscopic quantum states and pave the way for its application in spintronic devices.

MA 13.9 Tue 11:30 H43

Confinement of Bose-Einstein magnon condensates in adjustable complex magnetization landscapes — •Matthias R. Schweizer, Alexander J.E. Kreil, Georg von Freymann, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany

We demonstrate the capability to control a room-temperature magnon Bose–Einstein condensate (BEC) by spatial modulation of the saturation magnetization. We use laser heating in combination with a phase-based wavefront modulation technique to create adjustable temperature patterns in an yttrium-iron-garnet film. The increase in temperature leads to a decrease of the local saturation magnetization and in turn to the modification of the corresponding BEC frequency. Over time, a phase accumulation between different BEC-areas arizes, leading to phase-driven magnon supercurrents.

The BEC is created by microwave parametric pumping and probed by Brillouin light scattering spectroscopy. We observe a strong magnon accumulation effect caused by magnon supercurrents for several distances between heated regions. This accumulation effect manifests in the confinement of the magnon BEC, which exhibits an enhanced lifetime due to the continuous influx of magnons. The experimental results are supported by a numerical model, based on the hydrodynamic approximation of the Gross–Pitaevskii equation.

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MA 13.10 Tue 11:45 H43

New magnetostatic modes in biaxial magnets — •Yue Sun[1,2], Changmin Lee[2], Linda Ye[3], Shingo Toyoda[1,2], Veronika Sunko[1,2], Joseph Checkelsky[4], and Joseph Orenstein[1,2] — [1]University of California, Berkeley, Berkeley, California, USA — [2]Lawrence Berkeley National Laboratory, Berkeley, California, USA — [3]Stanford University, Stanford, California, USA — [4]Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Easy-plane antiferromagnets have been demonstrated to have long-distance magnon propagation and flexible control of ultrafast magnetic dynamics. However, exact XY systems are rare, and it is common to have a small in-plane crystalline easy-axis, which leads to the great interest in biaxial magnets. Spin superfluidity has been predicted in biaxial antiferromagnet in an applied magnetic field. Here, we discover new magnetostatic modes in both biaxial ferromagnet and antiferromagnet, where the interesting biaxial anisotropy opens new ranges for magnon frequency. We observe the new magnetostatic modes in biaxial ferromagnet Fe_3Sn_2, and the prediction of the magnetostatic modes in biaxial antiferromagnet matches with the experimental observations in CrSBr. Comparing to the spin wave induced by the exchange interaction, the magnetostatic modes dominate in the long wavelength limit and offer a unique possibility to observe magnon Bose-Einstein condensation in biaxial antiferromagnet.

MA 13.11 Tue 12:00 H43

Features of magnon spectra in conductive altermagnet: ab

initio calculations — •Alberto Marmodoro[1], Ondřej Šipr[1,2], and Tomas Jungwirth[1] — [1]Institute of Physics (FZU) of the Czech Academy of Sciences, Prague, Czech Republic — [2]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

Altermagnets [1] are materials with zero net magnetization, alike traditional antiferromagnets, as well as a characteristic alternation of spin polarization for the electronic structure in reciprocal space, due to the relative orientation for anisotropic crystal field effects on different magnetic sublattices in direct space. This may have significant implications for possible spintronics and nano-electronics applications. We report on ongoing work for the ab initio study of transverse magnon excitations in the case of the conducting, colinear antiferromagnetic altermagnet material RuO2

[1] arXiv 2105.05820v2

MA 13.12 Tue 12:15 H43

Beating Fabry-Pérot interference pattern in a magnonic scattering junction in the graphene quantum Hall ferromagnet — •Jonathan Atteia[1,2], François Parmentier[3], Preden Roulleau[3], and Mark-Oliver Goerbig[2] — [1]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Laboratoire de Physique des Solides, Université Paris Saclay, CNRS UMR 8502, F-91405 Orsay Cedex, France — [3]SPEC, CEA, CNRS, Université Paris-Saclay, CEA Saclay, F-91191 Gif sur Yvette Cedex, France

At filling factor $\nu = 0, \pm 1$, the ground state of graphene is a particular SU(4) ferromagnet which hosts a rich phase diagram along with several spin, pseudospin or "entanglement" magnon modes. Motivated by recent experiments, we study a $\nu = -1|0| - 1$ Fabry-Pérot magnonic junction. If the ground state at $\nu = 0$ is spin polarized, there exist two spin modes which interfere and create a beating pattern, while pseudospin modes are reflected. The same scenario occurs for pseudospin magnon if the $\nu = 0$ ground state is pseudospin polarized. The observation of such an interference pattern would provide information on the low-energy anisotropies and thus on the ground state.

MA 14: Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions

Time: Tuesday 9:30–12:00 Location: H47

Invited Talk MA 14.1 Tue 9:30 H47

Overriding universality of ferromagnetic phase transitions through nano-scale materials design — •Andreas Berger — CIC nanoGUNE BRTA, E-20018 San Sebastian, Spain

In recent years, significant interest has developed in magnetic thin films, in which the exchange coupling strength is ferromagnetic everywhere, but locally varying by means of nano-scale materials design. This interest is associated with the fact that such designed materials profiles translate into strongly varying magnetization states down to the 1-2 nm length scale, which is somewhat surprising, given that ferromagnetism is a collective phenomenon [1]. Correspondingly, such exchange-graded magnetic materials have shown themselves to be a very efficient way of modifying magnetic properties of otherwise rather conventional materials [1]. The most impressive result is hereby the possibility to tune critical exponents, in particular the magnetization onset exponent β in an extremely wide parameter range, which represents a unique way to override the universality usually associated with phase transitions of ferromagnets [2]. The same approach also enabled a complete separation of the temperature dependent onset of ferromagnetism at the Curie temperature from the onset of hysteresis, even in anisotropic materials [3], and it allowed for an enhancement of magnetocaloric properties [4]. Thus, exchange-graded materials are an extremely promising way to design the thermal evolution of magnetic properties and adapt it to device requirements. [1] Phys. Rev. B 98, 064404 (2018); [2] Phys. Rev. Lett. 127, 147201 (2021); [3] Phys. Rev. Appl. 16, 034038 (2021); [4] J. Phys. D 54, 304003 (2021).

MA 14.2 Tue 10:00 H47

Poisson-Dirichlet distributions and weakly first-order spin-nematic phase transitions — •Nils Caci[1], Peter Mühlbacher[2], Daniel Ueltschi[2], and Stefan Wessel[1] — [1]RWTH Aachen University, Aachen, Germany — [2]University of Warwick, Coventry, United Kingdom

Weakly first-order transitions, i.e. discontinuous phase transitions with very large correlation lengths, have become a vivid subject in condensed matter research and beyond in recent years. Therefore, establishing quantum systems in which weakly first order phase transitions can be robustly demonstrated is of great interest. We present a quantitative characterization of generic weakly first-order thermal phase transitions out of planar spin-nematic states in three-dimensional spin-one quantum magnets, based on calculations using Poisson-Dirichlet distributions (PD) within a universal loop model formulation, combined with large-scale quantum Monte Carlo calculations. In contrast to earlier claims, the thermal melting of the nematic state is not continuous, instead we identify a weakly first-order transition. Furthermore, we obtain exact results for the order parameter distribution and cumulant ratios at the melting transition. Our findings establish the thermal melting of planar spin-nematic states as a generic platform for quantitative approaches to weakly first-order phase transitions in quantum systems with a continuous SU(2) internal symmetry.

MA 14.3 Tue 10:15 H47

Derivation of Spin Hamiltonian by Algebraic Methods — •Hiroshi Katsumoto[1], Fabian Lux[1,2], Yuriy Mokrousov[1,2], and Stefan Blügel[1] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Complex magnetism is known to emerge from competing Heisenberg interactions and higher-order spin interactions [1]. In addition, previously unknown interactions such as the Chiral-Chiral interaction due to topological orbital magnetism turn also out to be essential to explain the magnetic properties [2]. However, a method for uniquely deriving spin Hamiltonians that captures the spin interactions of a given system has not yet been established. In this presentation, we give rigorous spin Hamiltonians for isotropic spin interactions for a given total localized spin S and the number of magnetic sites. The derivation of the spin Hamiltonian is based on the algebraic structure that the spin operators follow for arbitrary spin magnitude. By organizing the algebraic structure obeyed by the general spin operators, we discuss the construction of the exact spin Hamiltonian and the higher-order terms of interactions, especially for the cases $S = 1/2$ and 1.

We acknowledge funding from the European Research Council grant 856538 (project "3D MAGIC"); and Deutsche Forschungsgemeinschaft (DFG) through SPP-2137 and SFB-1238 (project C1).

[1] M. Hoffmann *et al.*, Phy. Rev. B **101**, 024418 (2020).
[2] S. Grytsiuk *et al.*, Nat. Commun. **11**, 511 (2020).

MA 14.4 Tue 10:30 H47

***Ab initio* approach to compute magnetic Gibbs free energies and phase transitions using magnetically constrained supercells** — •Eduardo Mendive Tapia[1,2,3], Nicolas Essing[1], Rudolf Zeller[1], Stefan Blügel[1], Jörg Neugebauer[2], and Tilmann Hickel[2] — [1]Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Max-Planck-Institut für Eisenforschung, 40237 Düsseldorf, Germany — [3]Universitat de Barcelona, D-08028 Barcelona, Spain

We present a first-principles approach for the computation of the magnetic Gibbs free energy of materials using magnetically constrained supercell calculations [1]. Our approach, based on an adiabatic approximation for the local moment orientations [2], describes magnetic phase transitions and how electronic and magnetovolume mechanisms generate a discontinuous (first-order) character. Results obtained for bcc Fe and the triangular antiferromagnetic state of Mn_3AN (A = Ga, Ni) [3] will be presented and used to explain their negative volume expansion and the first-order nature observed experimentally. The performance of two different density functional theory codes, the Vienna Ab Initio Simulation package (VASP) and the linear-scaling KKR-nano code suitable for thousands of atoms (https://jukkr.fz-juelich.de), will be shown.

[1] E. Mendive-Tapia, J. Neugebauer, T. Hickel, Phys. Rev. B **105**, 064425 (2022).
[2] B. Gyorffy *et al.*, J. Phys. F: Met. Phys. **15** 1337 (1985).
[3] D. Boldrin *et al.*, Phys. Rev. X **8** 041035 (2018).

MA 14.5 Tue 10:45 H47

spin-reorientation in CuCr2S4 from muSR — •elaheh sadrollahi[1], jochen litterst[2], lilian prodan[3,4], vladimir tsurkan[3,4], and alois loidl[3] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, Germany — [2]Institut für Physik der kondensierten Materie, Technische Universität Braunschweig, Germany — [3]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [4]Institute of Applied Physics, MD 2028, Chisinau, Republic of Moldova

Muon Spin Relaxation and Rotation (muSR) experiments have been performed on the thio spinel CuCr2S4 for further clarifying the long-standing controversy regarding its electronic and magnetic states [1,2]. Long regarded as ferromagnet (Tc=378 K) with magnetic moments residing only on Cr, CuCr2S4 is nowadays considered a ferrimagnetic with small magnetic moments on the Cu sites [3]. In addition to the transition at Tc, our muSR data reveal transitions around 50 K and 100 K with changes in spontaneous rotation signals and in relaxation behaviour. There is a close resemblance between these muSR results with those found for Fe1-xCuxCr2S4 with high Cu concentrations [4]. We interpret the transitions with spin re-orientations and will discuss the Jahn-Teller effect as a possible reason.[1] F. K. Lotgering et al., J. Phys. Chem. Solids 30, 799 (1969) and Solid State Commun. 2, 55 (1964). [2] J. B. Goodenough, Solid State Commun. 5, 577 (1967) and J. Phys. Chem. Solids 30, 261 (1969).[3] A. Kimura et al., Phys. Rev. B 63,224420 (2001).[4] E. Sadrollahi, Doctoral Thesis (2018): https://publikationsserver.tubraunschweig.de/receive/dbbs_mods_00066058.

MA 14.6 Tue 11:00 H47

identification of a new hidden-order phase in the magnetic phase diagram of $Ce_3Pd_{20}Si_6$ — •F. Mazza[1], P. Y. Portnichenko[2], P. Steffens[3], M. Boehm[3], E. S. Choi[4], M. Nikolo[5], S. Paschen[1], and D. S. Inosov[2] — [1]TU Wien, Austria — [2]TU Dresden, Germany — [3]ILL, Grenoble, France — [4]Florida State University, Tallahassee, USA — [5]St. Louis University, USA

Magnetically hidden order is a hypernym for electronic ordering phenomena whose microscopic symmetry cannot be revealed with conventional neutron or x-ray diffraction. In a handful of f-electron systems, the ordering of odd-rank multipoles leads to order parameters with a vanishing neutron cross-section. Among them, $Ce_3Pd_{20}Si_6$ is known for its unique phase diagram exhibiting two distinct multipolar-ordered ground states (phases II and II′), separated by a field-driven quantum phase transition. Using torque magnetometry at subkelvin temperatures, here we find another phase transition at higher fields above 12 T, which appears only for low-symmetry magnetic field directions. While the order parameter remains unknown, this discovery renders $Ce_3Pd_{20}Si_6$ the first known material with two metamultipolar phase transitions. They are both clearly manifested in the magnetic-field dependence of the field-induced (111) Bragg intensities measured with neutron scattering for $\mathbf{B} \parallel [11\bar{2}]$. Furthermore, the magnetic excitation spectrum suggests that the new phase II″ may have a different propagation vector in the vicinity of $\mathbf{Q} = (010)$, revealed by the minimum in the dispersion representing the Goldstone mode of this hidden-order phase.

MA 14.7 Tue 11:15 H47

Magnetic and thermodynamic properties of van-der-Waals $CuCrP_2S_6$ — •Kranthi Kumar Bestha[1,2], Laura Teresa Corredor Bohorquez[1], Vilmos Kocsis[1], Sebastian Selter[1], Saicharan Aswartham[1], Bernd Buechner[1,2], and Anja U. B. Wolter[1] — [1]Institute for Solid State Research, Leibniz IFW Dresden, 01069, Dresden, Germany — [2]Institute of Solid State and Materials Physics and Wuerzburg-Dresden Cluster of Excellence ct.qmat, Technical University Dresden, 01062 Dresden, Germany

Two-dimensional van-der-Waals materials with intrinsic multiferroic properties are advantageous over 3D multiferroic materials for next generation nanoscale magnetic and electric devices. $CuCrP_2S_6$ is a quasi-2D vdW multiferroic candidate with magnetic and ferroelectric polarization arising from Cr and Cu sublattices, respectively. $CuCrP_2S_6$ exhibits intralayer ferromagnetic and interlayer antiferromagnetic interactions. $M(T)$ and $Cp(T)$ on single crystal $CuCrP_2S_6$ reveal antiferromagnetic ordering at T_N=31.5 K. Our magnetic data reveal predominant ferromagnetic interactions below the ordering temperature and short-range ferromagnetic correlations above T_N. Magnetic fields applied in the ab-plane exhibit a spin-flop transition at a relatively small magnetic field of 4.3 kOe with weak anisotropy in the ab-plane. For a clear understanding of the magnetic anisotropy of this material, in-plane and out-of-plane angular-dependent dc magnetic studies were performed. Different symmetries are observed for both the in- and out-of-plane angular-dependent data. Our results are summarized in H-T phase diagrams for different main directions.

MA 14.8 Tue 11:30 H47

Probing magneto-elastic coupling in the quasi-2D van der Waals ferromagnet $Cr_2Ge_2Te_6$ — •Laura T. Corredor[1], Bastian Rubrecht[1,2], Takahiro Sakurai[3], Hitoshi Ohta[4], Alexey Alfonsov[1], Sebastian Selter[1], Saicharan Aswartham[1], Vladislav Kataev[1], Anja U. B. Wolter[1], and Bernd Büchner[5] — [1]Institute for Solid State Research, Leibniz IFW Dresden, 01069 Dresden, Germany — [2]Institute for Solid State and Materials Physics, TU Dresden, 01062 Dresden, Germany — [3]Research Facility Center for Science and Technology, Kobe University, Kobe 657-8501, Japan — [4]Molecular Photoscience Research Center, Kobe University, Nada, Kobe 657-8501 Japan — [5]Institute of Solid State and Materials Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

The first 2D uniaxial ferromagnetic semiconductor $Cr_2Ge_2Te_6$ -with a layered structure-is promising for exciting new applications such as ultra-compact spintronics or magnonic devices, which need 2D long-range magnetic order as crucial feature. Since magnetocrystalline anisotropy is essential for the stabilization of magnetic order in 2D spin systems, the possibility to control it via a tunable external parameter-such as pressure or strain- can provide useful hints for the engineering of magneto-electric heterostructures with strained architectures. With this motivation, magnetization and ferromagnetic resonance (FMR) experiments under hydrostatic pressure on $Cr_2Ge_2Te_6$ single crystals were performed. Insights on the magneto-elastic coupling and magnetic interactions with the increase of pressure are discussed.

MA 14.9 Tue 11:45 H47

Spin structure of Frenkel excitons on Cu^{2+}-ions in the antiferromagnet CuB_2O_4 revealed by magneto-absorption spectroscopy — •Dennis Kudlacik[1], Natalia E. Kopteva[1], Dimitri R. Yakovlev[1], Mikhail V. Eremin[3], Alexey R. Nurmukhametov[3], Manfred Bayer[1], and Roman V. Pisarev[2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]St. Petersburg, Russia — [3]Kazan, Russia

Frenkel excitons in magnetic insulators have attracted considerable interest in recent years as they allow the migration or transmission of a localized excitation. We have investigated this property which is reflected in the Davydov splitting of the exciton in the antiferromagnet copper metaborate, CuB_2O_4 [1]. This magnetic insulator consists of two weakly interacting sublattices of Cu^{2+} ions. Below the Neel temperature of T_N = 21 K its magnetic structure is dominated by the antiferromagnetic order of the 4b sublattice which comprises 4 Cu^{2+} ions twice degenerate in spin resulting in the formation of 8 collective charge-spin Frenkel-Davydov excitations. From a comparison of the experimental data with the results of the theoretical model we define the parameters of Frenkel exciton states, determine the electron-energy transfer between antiferromagnetically coupled copper spins as well as the anisotropic Cu^{2+} g-factors of ground and excited states.

[1] N. E. Kopteva et al., Phys. Rev. B 105, 024421 (2022).

MA 15: Computational Magnetism 2

Time: Tuesday 9:30–11:30 Location: H48

MA 15.1 Tue 9:30 H48

An *ab initio* study of temperature effects on the optical and magneto-optical properties of ferromagnetic BCC Fe — •Kisung Kang, David G. Cahill, and André Schleife — Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA

This work investigates the temperature-dependent optical properties of ferromagnetic BCC Fe in terms of electron, lattice, and magnetic temperatures. With the supercell approach, lattice and magnetic temperature is portrayed by the perturbed atomic and magnetic structures at finite temperature. In imaginary optical conductivity spectra at finite temperature, a large signal at low energy range is induced by phonon and magnon-assisted intraband transitions. We identify that this surging signal originates from the change of the dipole transition matrix elements. Magnetic temperature provokes a unique spectral change which is a redshift of the peak near 2.8 eV in the imaginary optical conductivity spectrum. From band unfolding analysis, it turns out that thermal demagnetization induces the reduction of exchange splitting in the electronic band structure, leading to the electron excitation with a smaller energy transition and explaining the peak redshifting. **Illinois MRSEC NSF DMR-1720633 Kisung Kang's present address: The NOMAD laboratory, Fritz-Haber-Institut der Max-Placnk-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

MA 15.2 Tue 9:45 H48

An ab-initio parameterised spin model of hematite — •Tobias Dannegger[1], András Deák[2], Shubhankar Das[3], E. F. Galindez Ruales[3], Eunchong Baek[3], Mathias Kläui[3], László Szunyogh[2,4], and Ulrich Nowak[1] — [1]Department of Physics, University of Konstanz — [2]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics — [3]Institute of Physics, Johannes Gutenberg University Mainz — [4]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics

The canted antiferromagnetic insulator hematite, known for motivating the theory of the Dzyaloshinskii–Moriya interaction [1, 2] as well as the first description of the Morin transition [3], is of interest in modern antiferromagnetic spintronics because of its long-distance spin transport properties [4]. We present an ab-initio parameterised atomistic spin model of hematite that accurately reproduces its magnetic properties and phase transitions, and shows how dipole-dipole interactions play an important role in determining the transition between the antiferromagnetic and weak ferromagnetic phase. We compare our model's predictions with extensive experimental measurements on a hematite single crystal and find good quantitative agreement across a wide range of temperatures.

[1] I. Dzyaloshinskii, *J. Phys. Chem. Solids* **50**, 241 (1958).
[2] T. Moriya, *Phys. Rev.* **120**, 91 (1960).
[3] F. J. Morin, *Phys. Rev.* **78**, 819 (1950).
[4] R. Lebrun et al., *Nature* **561**, 222 (2018).

MA 15.3 Tue 10:00 H48

The pyrochlore $s = 1/2$ Heisenberg antiferromagnet at finite temperature — •Robin Schäfer[1], Imre Hagymási[1,2], Roderich Moessner[1], and David Luitz[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Strongly Correlated Systems *Lendület* Research Group, Budapest, Hungary

We use state-of-the-art computational methods to investigate a frustrated three-dimensional quantum spin liquid candidate, the pyrochlore $s = 1/2$ antiferromagnet at finite temperature.

Using a systematic cluster expansion based on tetrahedra, including clusters up to 25 lattice sites with nontrivial hexagonal and octagonal loops, we gain access to various thermodynamic properties in the thermodynamic limit at finite temperature. We found a pronounced maximum in the specific heat at $T = 0.57J$ that is stable across finite size clusters and converged in the series expansion. At $T \approx 0.25J$ (the limit of convergence of our method), the residual entropy per spin is $0.47k_B \log(2)$, which is relatively large compared to other frustrated models at this temperature.

The generality of this algorithm allows us to investigate realistic compounds: Using recent experimental data on the dipolar-octopolar pyrochlore $Ce_2Zr_2O_7$, we were able to determine possible regions for the exchange parameters which give an accurate description of the high temperature regime.

MA 15.4 Tue 10:15 H48

Stabilisation of external-magnetic-field-induced magnetisation switching with respect to thermal fluctuations — •Grzegor J. Kwiatkowski[1], Mohammad H. A. Badarneh[1], and Pavel F. Bessarab[1,2] — [1]Science Institute of the University of Iceland, Reykjavík, Iceland — [2]Department of Physics and Electrical Engineering, Linnaeus University, Kalmar, Sweden

As magnetic memory devices are the cornerstone of data storage, rapid global growth of information transfer creates a pressing need for faster and more energy-efficient memory devices. One of the important directions of research is focused on optimizing the magnetization switching protocols [1,2] showing that both the amplitude of the external pulse as well as the switching time can be significantly reduced in comparison to currently used ones. Before those ideas are implemented one needs to test reliability of the designed optimal pulses when thermal fluctuations are present.

We present the effect of thermal fluctuations on the success rate of magnetization switching induced by an optimized external magnetic field pulse [1]. Furthermore, using perturbation theory and direct numerical simulations we systematically study how to increase the probability of switching by modifying the external pulse depending on the system parameters, temperature and chosen switching time.

[1] Kwiatkowski, G. J. et al. Phys. Rev. Lett., 126(17), 177206
[2] Badarneh, M. H. A. et al. F. Nanosyst.: Phys. Chem. Math., 11(3), 294-300

MA 15.5 Tue 10:30 H48

Energy-efficient control of magnetization reversal in nanoparticles — •Mohamamd Badarneh[1], Grzegorz Kwiatkowski[1], and Pavel Bessarab[1,2] — [1]Science Institute of the University of Iceland, 107 Reykjavik, Iceland — [2]Department of Physics and Electrical Engineering, Linnaeus University, Kalmar, Sweden

Control of magnetization switching is of critical importance for the development of novel technologies based on magnetic materials. Here we identify by means of optimal control theory energy-efficient protocols for magnetization switching in nanoparticles with uniaxial and biaxial anisotropy [1]. Optimal control paths minimizing the energy cost of magnetization reversal are calculated as functions of the switching time and materials properties, and used to derive energy-efficient switching pulses of external magnetic field. Hard-axis anisotropy reduces the minimum energy cost of magnetization switching due to activation of the internal torque in the desired switching direction. Analytical estimates quantifying this effect are obtained based on the perturbation theory. The optimal switching time providing a tradeoff between fast switching and energy efficiency is obtained. The energy cost of switching and the energy barrier between the stable states can be tuned independently in a biaxial nanomagnet. This provides a solution for the dilemma between energy-efficient writability and good thermal stability of magnetic memory elements. This work was funded by the Icelandic Research Fund (Grant No. 217813-052).

[1] G.J. Kwiatkowski et al., Phys. Rev. Lett. 126, 177206 (2021).

MA 15.6 Tue 10:45 H48

Exchange striction from first principles: how electron-phonon coupling modifies magnetic exchange — •Ryota Ono and Sergey Artyukhin — Italian Institute of Technology, Via Morego, 30, 16163 Genoa, Italy

Electron-phonon coupling refers to interactions between electrons and lattice distortions. We investigate how such coupling affects interactions between spins in solids. Ionic displacements from equilibrium positions modify overlap integrals between magnetic ions and ligands and thus modulate magnetic exchange. By extracting the self-consistent potential in the first-order in ionic displacements within the Born-Oppenheimer approximation, we obtain a general formula of the change in the one-electron Hamiltonian (electron-phonon coupling). The realistic electron-phonon coupling parameters entering a model Hamiltonian are accessible thorough the constrained density functional perturbation theory [1]. Using the obtained parameters, we construct a multiband Hubbard-like model. Finally, realistic magnetic interactions are obtained through Anderson's superexchange theory.

[1] Y. Nomura and R. Arita, Phys. Rev. B 92, 245108 (2015)

MA 15.7 Tue 11:00 H48

First principles theory of electron-magnon scattering and the spin polarized electron energy loss spectroscopy — •Sebastian Paischer[1], Pawel Buczek[2], Mikhail Katsnelson[3], and Arthur Ernst[1] — [1]JKU Linz — [2]HAW Hamburg — [3]Radboud University Nijmegen

Magnetic solids constitute a very important class of materials as they are extensively used in everyday life and are essential to many new technologies currently under development. In spite of their high relevance, some of the basic properties, like the interaction between electronic and magnetic degrees of freedom still remain a mystery. It leads to spin dependent lifetimes of electronic states and inelastic electron transport to name but a few. In our current study we investigate the impact of magnetic excitations on the electronic spectrum of solids as well as the scattering of high energy electrons with magnetic materials to formulate an ab initio theory for the spin polarized electron energy loss spectroscopy (SPEELS). Our approach is formulated in the framework of the formally exact many body GW theory. The novelty in our approach is that quantities from linear response time dependent density functional theory (LRTDDFT) calculations will be used to approximate an effective interaction between electrons and magnons. As our LRTDDFT calculations are based upon the Korringa-Kohn-Rostocker method, bulk systems as well as complex geometries can be accounted for. In this presentation, we sketch the theoretical basis of the electron-magnon scattering as well as the SPEELS theory and show several results.

MA 15.8 Tue 11:15 H48

The Complex Magnetic Structure and Giant Topological Hall Conductivity in Kagome Metal $YnMn_6Sn_6$ — •Hao Wang[1], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany.

The discovery of topological Kagome magnets attracts enormous research interest in recent years. The typical band structure of a Kagome lattice includes a flat band and a Dirac point. The high localized electrons induced strong many-body interactions in the flat bands and the linear dispersion of the Dirac point could lead to many intriguing physical phenomena, such as the quantum anomalous Hall effects, superconductivity, and the non-Fermi liquid behavior. Furthermore, the relationship between the complex noncolinear magnetic structures and band topology of the Kagome magnets also deserves further exploration. In this work, using first-principles calculation and spin Hamiltonian analysis, we investigated the complex magnetic structures, phase transition, and topological Hall conductivity of the Kagome metal YMn6Sn6. We confirm that the ground state of this material is a double flat-spiral structure, and we demonstrate the important role of thermal fluctuation in the origin of the giant Hall conductivity. This work provides a platform to understand the complex magnetic structure and topological properties of Kagome magnets for future spintronic devices.

MA 16: Frustrated Magnets

Time: Tuesday 15:00–17:45 Location: H37

MA 16.1 Tue 15:00 H37

Another Exact Ground State of a 2D Quantum Antiferromagnet — •Pratyay Ghosh, Tobias Müller, and Ronny Thomale — Institut für Theoretische Physik und Astrophysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland Campus Süd, Würzburg 97074, Germany

We present the exact dimer ground state of a quantum antiferromagnet on the maple-leaf lattice. A coupling anisotropy for one of the three inequivalent nearest-neighbor bonds is sufficient to stabilize the dimer state. Together with the Shastry-Sutherland Hamiltonian, we show that this is the only other model with an exact dimer ground state for all two-dimensional lattices with uniform tilings.

MA 16.2 Tue 15:15 H37

Pseudo-Majorana approach to Spin-Systems: Advanced Diagrammatics and Applications — •Björn Sbierski — LMU München, Germany

Frustrated three-dimensional quantum magnets bear a rich phenomenology but are notoriously hard to treat theoretically. We show how a SO(3) Majorana representation of spin operators, in combination with advanced diagrammatic techniques like the functional renormalization group or the parquet approximation allows for quantitative simulations at finite temperatures. We apply our method on various frustrated Heisenberg magnets. On the cubic lattice, we study magnetic phase transitions via finite-size scaling and we also present results for the Pyrochlore lattice. We also show how the method can be applied to meet some challenges of long-range interacting spin Hamiltonians arising in the context of Rydberg atom array quantum simulators.

Based on: [1] PRB 103.104431 (2021) [2] SciPost Phys. 12, 156 (2022)

MA 16.3 Tue 15:30 H37

Dynamical Spin Structure Factor of the spin-$\frac{1}{2}$ $J_1 - J_2$ Heisenberg Model on the Triangular Lattice — •Markus Drescher[1], Laurens Vanderstraeten[2], Roderich Moessner[3], and Frank Pollmann[1,4] — [1]TU München, 85748 Garching, Germany — [2]University of Ghent, 9000 Gent, Belgium — [3]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [4]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

The spin-$\frac{1}{2}$ Heisenberg model with antiferromagnetic nearest and next-to-nearest neighbour interactions on a triangular lattice exhibits—driven by the highly frustrated spins—a rich phase diagram and is relevant for various two-dimensional quantum materials. Using large-scale density matrix renormalization group simulations and time evolution algorithms for matrix product states, we obtain the dynamical spin structure factor of the triangular $J_1 - J_2$ Heisenberg model depicting the low-energy excitations both in the 120°-ordered phase at $J_2 = 0$ and the spin liquid phase at $J_2/J_1 = 0.125$. This method allows us to compare the low-energy properties of the isotropic Heisenberg model with previous analytical and numerical approaches.

In the ordered phase, we observe avoided decay of the lowest magnon branch. Our findings in the spin-liquid phase support the field-theoretical predictions by Song *et al.* [1,2], in particular the emergence of low-lying monopole excitations at the corners of the Brillouin zone.

[1] X.-Y. Song *et al.*, Nat. Comm. **10**, 4254 (2019).
[2] X.-Y. Song *et al.*, Phys. Rev. X **10**, 011033 (2020).

MA 16.4 Tue 15:45 H37

An Exact Chiral Amorphous Spin Liquid — •Peru d'Ornellas[1], Tom Hodson[1], Gino Cassella[1], Johannes Knolle[1,2,3], and Willian Natori[4] — [1]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom — [2]Department of Physics TQM, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [4]Institut Laue-Langevin, BP 156, 41 Avenue des Martyrs, 38042 Grenoble Cedex 9, France

The conventional wisdom has been that amorphous lattice structure would provide an obstacle to the formation of a long-range entangled ground states because of the inherent geometric disorder. Recently, symmetry protected topological phases have been proposed in non-interacting amorphous systems, raising the question of whether it is possible to construct a topologically ordered quantum many-body phase on an amorphous lattice. Here we provide such an example. We extend the Kitaev honeycomb Hamiltonian to amorphous lattices, constructed using the Voronoi method on a set of random points. The resulting model retains its exact solubility, displaying Abelian as well as a non-Abelian quantum spin liquid phases. However, the presence of plaquettes with an odd number of sides leads to a spontaneous breaking of time reversal symmetry, opening a gap in the non-Abelian phase. Furthermore, we show that the system undergoes a finite-temperature phase transition to a conducting thermal metal state. Possible experimental realisations in metal-organic frameworks are discussed.

MA 16.5 Tue 16:00 H37

Hole Spectral Function of a Chiral Spin Liquid in the Triangular Lattice Hubbard Model — •Wilhelm Kadow[1,2], Laurens Vanderstraeten[3], and Michael Knap[1,2] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Department of Physics and Astronomy, Ghent University, B-9000 Ghent, Belgium

Quantum spin liquids are fascinating phases of matter, hosting fractionalized spin excitations and unconventional long-range quantum entanglement. These exotic properties, however, also render their experimental characterization challenging and finding ways to diagnose quantum spin liquids is therefore a pertinent challenge. Here, we numerically compute the spectral function of a single hole doped into the half- filled Hubbard model on the triangular lattice using techniques based on matrix product states. At half filling the system has been proposed to realize a chiral spin liquid at intermediate interaction strength, surrounded by a magnetically ordered phase at strong interactions and a superconducting/metallic phase at weak interactions. We find that the spectra of these phases exhibit distinct signatures. By developing appropriate parton mean-field descriptions, we gain insight into the relevant low energy features. Our results suggest that the hole spectral function, as measured by Angle-Resolved Photoemission Spectroscopy (ARPES), provides a useful tool to characterize quantum spin liquids.

MA 16.6 Tue 16:15 H37

The nature of visons in the perturbed ferromagnetic and antiferromagnetic Kitaev honeycomb models — Chuan Chen[1] and •Inti Sodemann Villadiego[2,3] — [1]Institute for Advanced Study, Tsinghua University, 100084 Beijing, China — [2]Institut für Theoretische Physik, Universität Leipzig, 04103 Leipzig, Germany — [3]Max-Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

The Kitaev honeycomb model hosts a fascinating fractionalized state of matter that features emergent Majorana fermions and a vison particle that carries the flux of an emergent gauge field. In the exactly solvable limit, these visons are static, but perturbations can induce their motion.

We show that the nature of the vison motion is sharply distinct in the ferromagnetic vs the anti-ferromagnetic Kitaev models. Namely, in the ferromagnetic model the vison has a trivial non-projective translational symmetry, whereas in the anti-ferromagnetic Kitaev model it has a projective translational symmetry with pi-flux per unit cell. The visons of the FM case have zero Berry curvature, and no associated intrinsic contribution to the Thermal Hall effect. In contrast, in the AFM case and under a Zeeman perturbing field, there are two gapped vison bands with opposite Chern numbers and an associated intrinsic vison contribution to the Thermal Hall effect. We will comment on other results in the literature that are in disagreement with ours (arXiv:2109.00250, 2021) and discuss the potential connections of our findings to the physics of the spin liquid candidate alpha-RuCl_3.

MA 16.7 Tue 16:30 H37

Magnetism in a distorted kagome lattice: the case of Y-kapellasite — •Aleksandar Razpopov[1], Max Herring[2], Francesco Ferarri[1], Igor Mazin[3], Roser Valenti[1], Harald Jeschke[4], and Johannes Reuther[2] — [1]Goethe University, Frankfurt, Germany — [2]Free University of Berlin, Berlin, Germany — [3]George Mason University, Washington DC, United States — [4]Okayama University, Okayama, Japan

Compounds like the well-known Herbertsmithite are examples of the ideal spin-1/2 antiferromagnetic (AFM) kagome lattice which has one of the most interesting magnetic phase diagrams. However, while the perfect AFM kagome lattice has been extensively investigated, less is known about distorted kagome lattices.

Here we focus on an unexplored distorted spin-1/2 kagome lattice with three symmetry-inequivalent nearest-neighbor AFM Heisenberg couplings. The recently synthesized Y-kapellasite $Y_3Cu_9(OH)_{19}Cl_8$ is a realization of such a distorted lattice. First, we analyse the classical magnetic phase diagram using analytical arguments and numerical methods, and find a rich classical phase diagram with a Q=0 magnetic phase, Q=(1/3,1/3) non-collinear coplanar magnetic phases and a classical spin liquid regime. In a second step we estimate the effective magnetic Heisenberg Hamiltonian by total-energy mapping analysis within the FPLO framework. Using the extracted Heisenberg Hamiltonian we predict Y-kapellasite to be localized in the Q=(1/3,1/3) phase which is stable after inclusion of quantum effects.

MA 16.8 Tue 16:45 H37

Thermodynamic and magnetic properties of the rare-earth delafossite $NaGdS_2$ — •Justus Grumbach[1], Mathias Doerr[1], Ellen Haeussler[2], and Sergey Granovsky[1] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062 Dresden, Germany. — [2]Fakultät für Chemie und Lebensmittelchemie, Technische Universität Dresden, 01062 Dresden, Germany

Rare-earth delafossites are materials containing ideal triangular magnetic planes which are frustrated. Due to their properties, rare-earth delafossites are promising candidates for a QSL ground state. In recent years, research has focused on $S = \frac{1}{2}$ delafossites where either QSL or AFM ground states occur, with transitions in the mK range (e.g. [1] vs. [2]).

Now a number of new measurements have been made on $NaGdS_2$ single crystals with the pure spin moment $J = S = \frac{7}{2}$ of the Gd^{3+} magnetic ion. Measurements of several thermodynamic and magnetic properties were performed on very small samples (size $\sim \mu$m) down to 40 mK. Essential physical data could be extracted which consistently show a magnetic ordered AFM ground state below ∼200 mK.

[1] G. Bastien et al., SciPost Phys. 9, 041 (2020)
[2] M. Baenitz et al., Phys Rev B 98, 220409(R) (2018)

MA 16.9 Tue 17:00 H37

Single crystal study of the magnetic phase diagrams in $BaCo_2(PO_4)_2$ — •Xiao Wang[1], Rohit Sharma[1], Petra Becker-Bohatý[2], Ladislav Bohatý[2], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany — [2]Abteilung Kristallographie, Institut für Geologie und Mineralogie, Universität zu Köln, Zülpicher Straße 49b, 50674 Köln, Germany

The study of the Kitaev materials has been an active area in the past decades, mainly motivated by their novel physical properties such as topological order, exotic excitations and potential application for quantum computing . Motived by recent theoretical proposals that Kitaev model might be realized in $3d$ transition-metal compounds , we have successfully synthesized single crystal samples of $BaCo_2(PO_4)_2$. Our work on the high-quality $BaCo_2(PO_4)_2$ sample unveils a sharp phase transition at ∼3.5K which signals the evolution of antiferromagnetic long-range order in zero magnetic field. Such a transition is not observed in previous studies on polycrystalline $BaCo_2(PO_4)_2$ [3], while for a $T_N = 5.4$ K is reported for $BaCo_2(AsO_4)_2$ [4]. Here we present a comprehensive study of the magnetic phase transitions by magnetization, specific heat and thermal expansion measurements and construct the magnetic phase diagram of $BaCo_2(PO_4)_2$. This work is funded by the DFG via CRC 1238 Projects A02 and B01.

[1] A. Kitaev, Ann. Phys. (N. Y). 321, 2 (2006) [2] H. Liu, et al. Phys. Rev. Lett. 125, 3 (2020) [3] H. S. Nair, et al. Phys. Rev. B 97, 1 (2018) [4] R. Zhong, et al. Sci. Adv. 6, 1 (2020)

MA 16.10 Tue 17:15 H37

Resonant X-ray and neutron investigation of the double perovskite Nd_2ZnIrO_6 — •Fabian Stier, Marein Rahn, and Jochen Geck — Institut für Material- und Festkörperphysik, TU Dresden, Deutschland

We present a study of the magnetic order in the double perovskite Nd_2ZnIrO6 as a function of temperature and magnetic field. This material contains Ir with a formal valence of 4+, which is is very often described in terms of localized j=1/2 states. The magnetism of such j=1/2 states has attracted much attention, especially in relation to the possible formation of quantum spin liquids in actual materials. In order to elucidate the magnetism of the Nd 4f- and the Ir 5d-electrons in Nd2ZnIrO6, we performed resonant magnetic x-ray scattering and neutron powder diffraction. Below T_N=15 K we observe magnetic order with propagation vector (0.5 0.5 0) and moments in the ab plane. The temperature dependence reveals the Ir moment as the driving force of the magnetic ordering below T_N. Applying a magnetic field along the crystallographic a-direction at T=5K causes a metamagnetic transition to a phase with a propagation vector (0 0 0). Interestingly, applying the magnetic field along the crystallographic c-direction shows a linear field dependence.

MA 16.11 Tue 17:30 H37

Pressure induced multicritical behaviour in a kagome ferro-

magnet — •Arvind Maurya — Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany

We report high quality single crystal growth of ferromagnetURhSn, crystallizing in ZrNiAl- type hexagonal structure in which the magnetic U-atoms form potentially frustrated quasi-kagome two-dimensional net. Our measurements of electrical transport under hydrostatic pressures up to 11 GPa reveals two bicritical points concurrent at P_C = 6.25 GPa corresponding to its successive double phase transitions (T_O = 54 K, T_C = 18 K at ambient). Rermakably, the intermediate phase remains hidden as local probes like neutron scattering and Mössbauer spectra do not capture any new feature across the T_O. Our low temperature resistivity data under pressure points out a Fermi surface reconstruction across the P_C, corresponding to an unconventional class of quantum phase transition involving multicritical points. This picture is further ascertained by gradual development of -ln$T$ behavior in 5f-derived electrical resistivity and appearance of $T^{5/3}$ dependence in the pressure induced phase.

MA 17: PhD Focus Session: The Hitchhiker's Guide to Spin Phenomena at the Space and Time Limit

The growing hunger of society for fast data storage and processing, together with the end of Moore's law, demand the development of new technologies to implement smaller, faster and more power-efficient devices. Research in magnetic materials has shown the potential of spin-based devices in this regard. Pushing for 'More than Moore' devices, space and time limits need to be tackled. At the heart of this research are three fundamental operations: Control of magnetic order, spin transport and efficient monitoring of spin angular momentum in space and time. Topical clusters ranging from ferro- to antiferromagnets up to 2D materials, magnetic-organic interfaces and heterostructures are extensively studied. New materials and concepts are being developed rapidly which can appear very complex to someone new to the field. Young researchers often manage to get an overview of their own specific field but lack the big picture. For this reason, this PhD symposium will focus on talks in mostly tutorial-like style, yet will also include recent highlights. In addition, the symposium aims to exchange ideas and foster discussions on a broad range of spin phenomena. Organizers: Yannic Behovits (Physics, Freie Universität Berlin and Fritz Haber Institute of the MPS), Mona Bhukta (Physics, Johannes Gutenberg University Mainz), Bikash Das Mohapatra (Physik, Martin-Luther-Universität Halle-Wittenberg), Oliver Gueckstock (Physics, Freie Universität Berlin and Fritz Haber Institute of the MPS), Hendrik Meer (Physics, Johannes Gutenberg University Mainz), Maximilian Paleschke (Physik, Martin-Luther-Universität Halle-Wittenberg), Eva S. Walther (Physics, Technische Universität Kaiserslautern).

Time: Tuesday 15:00–17:00 Location: H43

Invited Talk MA 17.1 Tue 15:00 H43

Ultimately fast, small and energy-efficient magnetism: fundamentals and prospects — •Johan Mentink — Radboud University, Nijmegen, The Netherlands

Findings ways to switch between magnetically ordered states at the smallest possible length and time scale, while simultaneously dissipating the least amount of energy is a major challenge in magnetism. One of the most appealing routes to achieve this goal is by bringing a magnetic system strongly out of equilibrium, after which the dynamics is driven by exchange interaction, the strongest force in magnetism. Although this has been extensively discussed in ferrimagnetic systems, harnessing such exchange-driven dynamics in ferromagnets is fundamentally limited by angular momentum conservation. We will discuss basic models of magnetism that can be solved even under strongly nonequilibrium conditions and have been key to identify the mechanisms for ultrafast switching. We will exemplify this for chiral ferromagnets as studied by recent XFEL experiments. For this case, the nonequilibrium dynamics is driven by an additional antisymmetric exchange interaction, resulting in ultrafast nucleation of nanoscale magnetic skyrmions. This opens a new path for switching that is not only fast, but also can operate at the nanoscale. By comparing with the fundamental energy-speed limits for switching between physically distinct states, we will argue that such exchange-driven dynamics can be key to achieve even faster, smaller and much more energy-efficient switching than demonstrated so far.

Invited Talk MA 17.2 Tue 15:30 H43

From spintronics at limiting temporal and spatial scales in antiferromagnets to an emerging altermagnetic phase — •Tomas Jungwirth — Institute of Physics, Czech Academy of Sciences and University of Nottingham, UK

Magnetically ordered crystals are traditionally divided into two basic phases – ferromagnetism and antiferromagnetism. In the first part of the talk, we will recall that the ferromagnetic order offers a range of phenomena and existing device applications, while the vanishing net magnetization in antiferromagnets is potentially favorable for temporal and spatial scalability of spintronic devices. In the second part of the talk we will move on to the recent predictions of instances of strong time-reversal symmetry breaking and spin splitting in electronic bands, typical of ferromagnetism, in crystals with antiparallel compensated magnetic order, typical of antiferromagnetism. This apparent fundamental conflict in magnetism is resolved by symmetry considerations that allow us to classify and describe a third basic magnetic phase. Its alternating spin polarizations in both crystal-structure real space and electronic-structure momentum space suggest a term altermagnetism. We will demonstrate that altermagnets combine merits of ferromagnets and antiferromagnets, that were regarded as principally incompatible, and have merits unparalleled in either of the two traditional basic magnetic phases. We will show that they underpin a development of a new avenue in spintronics based on strong non-relativistic spin-conserving phenomena, without magnetization imposed scalability limitations, and with complex logic-in-memory functionalities.

Invited Talk MA 17.3 Tue 16:00 H43

An electronic structure viewpoint on candidate van der Waals ferromagnets — •Phil King[1], Matt Watson[1], Brendan Edwards[1], Akhil Rajan[1], Jiagui Feng[1], Deep Biswas[1], Monica Ciomaga Hatnean[2], Amelia Hall[2], Geetha Balakrishnan[2], Giovani Vinai[3], David Burn[4], Thorsten Hesjedal[5], Gerrit van der Laan[4], Oliver Dowinton[6], and Saeed Bahramy[6] — [1]Univ. St Andrews — [2]Univ. Warwick — [3]Elettra synchrotron — [4]Diamond Light Source — [5]Univ. Oxford — [6]Univ. Manchester

Control over materials thickness down to the single-atom scale has emerged as a powerful tuning parameter for manipulating both single-particle band structures and collective states of solids. Magnetism is a new frontier in the study of 2d materials. Here, I will show how direct measurement of the electronic structure using angle- resolved photoemission (ARPES) can lead to valuable insight not only into whether a 2d material exhibits long-range magnetic order, but also on its microscopic mechanisms. I will consider monolayer VSe_2, where a putative magnetic order is destabilised by the formation of a robust charge density wave,[1,2] but can be re-established via proximity coupling;[3] $V_{1/3}NbS_2$, where proximity coupling to the surface layer can lead to a modulation of spin-valley locking, and $CrGeTe_3$, an established van der Waals ferromagnet, where band structure measurements provide important microscopic insights even in a local moment system.[4] [1]Rajan et al., Phys. Rev. Materials 4 (2020) 014003; [2]Feng et al., Nano Lett. 18 (2018) 4493; [3]Vinai et al., Phys. Rev. B 101 (2020) 035404 ; [4]Watson et al., Phys. Rev. B 101 (2020) 205125.

Invited Talk MA 17.4 Tue 16:30 H43

Nano-scale skyrmions and atomic-scale spin textures studied with STM — •Kirsten von Bergmann — Department of Physics, University of Hamburg, Germany

Non-collinear magnetic order arises due to the competition of different magnetic interactions. Often the dominant interaction is the isotropic pair-wise exchange between neighboring atomic magnetic moments. An additional sizable contribution from anisotropic exchange (Dzyaloshinskii-Moriya-Interaction) typically leads to spin spiral ground states in the absence of magnetic fields. In applied magnetic fields such systems can transition into skyrmion lattices or isolated skyrmions with diameters down to a few nanometers.

In zero magnetic field single skyrmions can arise as metastable states, stabilized by frustrated exchange interactions, which originate from competing non-negligible exchange interaction to more distant magnetic moments [1]. Periodic two-dimensionally modulated magnetic states on the atomic scale can arise due to higher-order magnetic interactions. Such higher-order interactions can favor superpositions of spin spirals, so called multi-q states. Depending on the sample system atomic scale non-collinear magnetic lattices of different symmetry and size can form [2]. Higher-order interactions can also determine the type and width of domain walls in antiferromagnets [3].

[1] S. Meyer et al., Nature Commun. 10, 3823 (2019).
[2] M. Gutzeit et al., arXiv:2204.01358.
[3] J. Spethmann et al., Nature Commun. 12, 3488 (2021).

MA 18: Spintronics

Time: Tuesday 15:00–17:15 Location: H47

MA 18.1 Tue 15:00 H47

Multilayer on-chip spintronic THz emitters — •Wolfgang Hoppe[1], Mohamed Amine Wahada[2], Stuart S. P. Parkin[2], and Georg Woltersdorf[1] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Nanometer thin ferromagnet/heavy metal bilayers illuminated by intense, short laser pulses have proven to be a reliable source for THz emission [1]. When integrated into a gold waveguide structure, the bilayer can be used as an on-chip source for ultrafast current pulses, ranging from the GHz to the THz regime [2]. One possible application is the switching of the magnetization of an adjacent magnetic layer [3]. A way to achieve the needed threshold current density is by increasing the amplitude of the current-pulses. This can be accomplished by stacking the bilayers, each separated by a thin MgO interlayer impeding the formation of any spin-currents in between the individual bilayers [4]. Here, the charge current in all bilayers can add, leading to an enhanced signal. We demonstrate an increase by a factor of three for the optimal stacking configuration. The multilayers are investigated by electro-optic sampling.

[1] Seifert et al. Nature Photon 2016, 10, 483-488
[2] W. Hoppe et al. ACS Appl. Nano Mater. 2021, 4, 7, 7454-7460
[3] Y. Yang et al. Sci. Adv. 2017, 3, 11
[4] M. A. Wahada et al. ACS Nano Lett. 2022, 22, 9, 3539-3544

MA 18.2 Tue 15:15 H47

Ab initio studies of chiral crystals for generalized linear response transport and x-ray absorption spectroscopy — •Alberto Marmodoro[1], Hubert Ebert[2], and Ondřej Šipr[1,3] — [1]Institute of Physics (FZU) of the Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Chemistry, Ludwig-Maximilians-University (LMU), Munich, Germany — [3]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

Materials with a chiral atomic arrangement exhibit specific electronic structure features [1]. The clock-wise or anti-clock-wise winding of sublattices has been associated with a radial spin texture of the Fermi surface in reciprocal space [2]. This provides interesting consequences for the response [3] to e.g. an applied electric field, for instance in terms of Edelstein effect and particularly its dependence on the sign of the perturbation. We report generalized linear response predictions [3] and theoretical x-ray spectroscopy cross-sections [4] for inorganic bulk crystals from first-principles studies performed within the frameworks of a spin-polarized relativistic Korringa, Kohn, Rostoker (SPRKKR) treatment.

[1] http://dx.doi.org/10.7566/JPSJ.83.061018
[2] http://dx.doi.org/10.1103/physrevlett.127.126602,
http://dx.doi.org/10.1038/s42005-021-00564-w
[3] http://dx.doi.org/10.1103/PhysRevB.91.165132
[4] http://dx.doi.org/10.1107/S090904959801680X

MA 18.3 Tue 15:30 H47

Studying Spin Dynamics of Thin $Cr_2Ge_2Te_6$, using Superconducting Resonators — •Christoph W. Zollitsch[1], Safe Khan[1], Nam Vu Thanh Trung[2], Dimitrios Sagkovits[1], Ivan Verzhbitskiy[2], Goki Eda[2], and Hidekazu Kurebayashi[1] — [1]London Centre for Nanotechnology, University College London, London WC1H 0AH, United Kingdom — [2]Department of Physics, National University of Singapore, 2 Science Drive 3, Singapore 117551

Two-dimensional van der Waals material systems gained an increased interest in the field of spintronics, as they can maintain ferromagnetic order even down to the few monolayer regime. These materials naturally permit device miniaturization. An ideal test bed for new spintronics applications in the 2D limit is the ferromagnetic semiconductor $Cr_2Ge_2Te_6$, where intrinsic ferromagnetism has been discovered for atomic bilayers [1].

We investigate the spin dynamics of thin exfoliated flakes (11 - 150 nm) of $Cr_2Ge_2Te_6$, using superconducting lumped element resonators made of NbN. The flakes are transferred directly on top of several superconducting resonator structures, featuring resonance frequencies from 12 GHz to 18 GHz. We perform ferromagnetic resonance (FMR) at a temperature of 1.8 K and can easily resolve the response from the flakes, even down to a thickness of 11 nm. With our multi-resonator approach, can confirm a Kittel FMR behaviour for the full thickness range. The FMR data can very well be described with bulk values of the magnetic parameters.

[1] Cheng Gong et al., Nature 546, 265-269 (2017)

MA 18.4 Tue 15:45 H47

Spin wave spectrum asymmetry from nonlocal chiral renormalization of gyromagnetic ratio — •Ivan Ado[1,2] and Mikhail Titov[2] — [1]Institute for Theoretical Physics, Utrecht University, 3584 CC Utrecht, The Netherlands — [2]Institute for Molecules and Materials, Radboud University, 6525 AJ Nijmegen, The Netherlands

We present a new potential source of the spin wave spectrum asymmetry in metallic and semiconducting magnets. Such an asymmetry is often used to experimentally measure the Dzyaloshinskii-Moriya interaction (DMI) strength using Brillouin light scattering (BLS). We argue that there exists an additional contribution to the asymmetry that originates in coupling between magnetic moments and charge carriers. Moreover, this contribution is sensitive to electron scattering by impurities and depends on the parameters of the electron diffusive motion. We address the corresponding mechanism as "nonlocal chiral renormalization of gyromagnetic ratio". We analyze it both microscopically and using symmetry arguments, for a prototypical 2D metallic ferromagnet. The resulting contribution to the asymmetry scales quadratically with the scattering time and thus can be particularly strong in sufficiently clean systems. We suggest that experimental measurements of DMI by means of BLS may be inaccurate if one does not take this effect into account.

MA 18.5 Tue 16:00 H47

Influence of dusting layers on the magneto-ionic response of Ta/X/CoFeB/Y/MgO/HfO2 thin film stacks — •Tanvi Bhatnagar-Schöffmann[1], Aurélie Solignac[2], Djoudi Ourdani[3], Rohit Pachat[1], Maria-Andromachi Syskaki[5], Yves Roussigné[3], Shimpei Ono[6], Dafiné Ravelosona[4], Jürgen

Langer[5], Mohamed Belmeguenai[3], and Liza Herrera Diez[1] — [1]Centre de Nanosciences et de Nanotechnologies, CNRS, Université Paris-Saclay, 91120 Palaiseau, France — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France — [3]Laboratoire des Sciences des Procédés et des Matériaux, CNRS-UPR 3407, Université Paris 13, Sorbonne Paris Cité, 93430 Villetaneuse, France — [4]Spin-Ion Technologies, C2N, 10 Boulevard Thomas Gobert, 91120 Palaiseau, France — [5]Singulus Technologies AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany — [6]Central Research Institute of Electric Power Industry, Yokosuka, Kanagawa 240-0196, Japan

Here,we present the room temperature magneto-ionic control of magnetic anisotropy,coercivity and DMI in Ta/X/CoFeB/Y/MgO/HfO2 ,where X and Y are dusting layers of heavy metal elements (Pt,W) sharing different interfaces with CoFeB. Dusting layers at the bottom interface (Y) can define a system locked in a PMA state allowing for a reversible magneto ionic control of coercivity, while samples with dusting layers at the top interface (X) can allow for a full and reversible spin-reorientation transition. The intercalation of dusting layers of heavy metal elements in Ta/CoFeB/MgO stacks has the potential to fine tune magnetic properties.

MA 18.6 Tue 16:15 H47

Anisotropic magnetoresistance in systems with non-collinear magnetic order — •Philipp Ritzinger and Karel Vyborny — Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, 182 21 Prague 8, Czech Republic

Since its discovery in 1857 by William Thomson, the anisotropic magnetoresistance (AMR) has been in focus of many theoretical studies seeking to understand the microscopic mechanisms of this effect. Most attention has been paid to ferromagnets (FMs) and recently, the scope of research on AMR is extended to include also antiferromagnets (AFMs). AMR can be due to anisotropic scattering (extrinsic) or an anisotropic Fermi surface (intrinsic). Here we focus on the latter, much less investigated intrinsic mechanism, which is achieved by considering non-collinear magnetic order inspired by real materials such as CrSe, delta-FeMn, Mn3Ge or RbFe(MoO4)2. We explore various types of lattices on toymodel level amongst which are trigonal, tetraedral or Kagome lattice. Magnetic moments can be arranged in many different ways on such lattices and seemingly small changes alter the Fermi surface symmetry, spin texture and transport properites. We have investigated systematically the influence of magnetic ordering on these properties which allows to predict general features of spin texture and transport by only considering the symmetry of the underlying system. As an example of these effects we have shown that AFM systems without spin-orbit coupling on Kagome lattices can develop anisotropy in the electric conductivity under applied in-plane magnetic field. This does not occur in FMs without spin-orbit coupling.

MA 18.7 Tue 16:30 H47

Spin-split collinear antiferromagnets: a large-scale ab-initio study — •Yaqian Guo[1], Hui Liu[1,2], Oleg Janson[1], Cosma Fulga[1,2], Jeroen van den Brink[1,2], and Jorge I. Facio[1,3,4] — [1]Leibniz Institute for Solid State and Materials Research, IFW Dresden, 01069 Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany — [3]Centro Atómico Bariloche and Instituto Balseiro, CNEA, 8400 Bariloche, Argentina — [4]Instituto de Nanociencia y Nanotecnología CNEA-CONICET, Argentina

Collinear antiferromagnetic (cAFM) materials can break the spin degeneracy in momentum space based on their magnetic symmetry, giving rise to the so called AFM-induced spin splitting. In this mechanism, spin splitting originates neither from a non-zero net magnetization (Zeeman effect) nor spin-orbit coupling (SOC) in noncentrosymmetric materials (Rashba-Dresselhaus effect), but from the magnetic symmetries. In this work, we performed a systematic analysis for 62 cAFM compounds and investigated the AFM-induced spin splitting without considering SOC. We established three measures to analyze the average spin splitting. Based on our measures, we identified the compounds with sizable spin splitting, such as CoF_2 and $FeSO_4F$, and analyzed their electronic structure in detail. A similar analysis was performed for particular low-dimensional magnets, e.g. $LiFe_2F_6$ and antiferromagnetic metals with spin splitting, e.g. RuO_2, $CrNb_4S_8$ and CrSb.

MA 18.8 Tue 16:45 H47

Superparamagnetic tunnel junctions for neuromorphic computing — •Leo Schnitzspan[1,2], Gerhard Jakob[1,2], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz — [2]Max Planck Graduate Center, Mainz

Superparamagnetic tunnel junctions (SMTJ) are promising candidates for the implementation of neuromorphic computing. In a SMTJ, the magnetic free layer can switch its orientation induced by thermal activation, leading to a random two-level resistance fluctuation with relaxation times in the order of a few nanoseconds [1]. Their intrinsic stochastic behaviour and additional tunability by external magnetic fields, Spin Transfer Torques (STT) or Spin Orbit Torques (SOT) are key ingredients for low-energy artificial neurons in neural networks. Non-conventional computing, like inverse logic for integer factorization already has been demonstrated based on SMTJs[2]. Measurements of the characteristic stochastic switching behaviour are highlighted and the quality of randomness (according to NIST Statistical Test Suite) for a SMTJ as a potential true random number generator is evaluated. New possible implementation ideas of a stochastic neural network based on SMTJs are proposed and their efficiency is studied in detail.

[1] Hayakawa, K. et al., Phys. Rev. Lett. 126, 117202 (2021). [2] Borders, W. A. et al., Nature 573, 390-393 (2019).

MA 18.9 Tue 17:00 H47

Simulation of Polymer Spintronics — •Shih-jye Sun — National University of Kaohsiung, Kaohsiung, Taiwan

We proposed a two-level model to simulate the spin-polarization current and the mobility in a field-effect transistor constructed by an antiferromagnetic-coupling polymer chain connected with the source, drain electrodes, and the oxide gate. This model is beyond the single-level model because of considering the inducing states in the polymer host by adding the magnetic functional side groups. We found that the double Coulombic excitations sensitively depend on the inducing states in the model significantly influencing the spin-polarization current and the mobility. Eventually, the workable organic spintronics can be realized based on our simulations.

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 resolved 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 $V_{zz} = 154(2)\,\mathrm{V/Å^2}$. 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.

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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.

References:
[1] A. Davidson *et al.*, Phys. Lett. A **384**, 126228 (2020).
[2] A. J. Berger *et al.*, Phys. Rev. B **97**, 94407 (2018).
[3] M. Meinert *et al.*, Phys. Rev. Applied **14**, 064011 (2020).
[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.

MA 20: Focus Session: Revealing Multidimensional Spin Textures and their Dynamics via X-rays and Electrons

Non-collinear spin textures in magnetic materials and excitations within such spin arrangements moved into the focus of research. These system host topological spin states and unique excitations providing access to versatile future spintronic applications. The imaging of such complex internal magnetic orders of materials is a fundamental problem of extreme importance for the successful implementation of these applications. Characterizing the electronic, magnetic and transport properties of structures such as vortices, magnetic singularities or hopfions lead to the development of novel experimental and theoretical techniques. For instance, magnetic hopfions have been unveiled via a combination of X-ray photoemission electron microscopy and soft X-ray transmission microscopy using element-specific X-ray magnetic circular dichroism effects. Recently, time-resolved magnetic laminography enabled access to the temporal evolution of three-dimensional (3D) magnetic microdiscs with nanoscale resolution, while quantitative reconstruction of the 3D spintexture of skyrmions with sub-10 nm resolution was demonstrated by holographic vector field electron tomography or soft x-ray vector ptychography. Pivotal to these experimental developments are theoretical proposals for the detection and manipulation protocols. Although making a strong impact in the field of magnetism, this area of research calls for an in-depth exchange between experts of different techniques, experimental and theoretical, to unravel many of the open questions and puzzling behavior discovered within the last couple of years. This motivates the present focus session as an opportunity for discussions and to attract more researchers to this fascinating field. Organizers: Samir Lounis (Uni.Duisburg-Essen and FZ-Jülich) Matthias Althammer, Stephan Geprägs (Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching), Gisela Schütz (MPI-Intelligent systems, Stuttgart), Stefan Blügel (FZ-Jülich)

Time: Wednesday 9:30–13:00 Location: H37

Invited Talk MA 20.1 Wed 9:30 H37

Recent developments in X-ray three-dimensional magnetic imaging — •Valerio Scagnoli — ETHZ - PSI

Three dimensional magnetic systems hold the promise to provide new functionality associated with greater degrees of freedom. Over the last years we have worked towards developing methods to fabricate and characterize three dimensional magnetic structures. Specifically, we have combined X-ray magnetic imaging with new iterative reconstruction algorithms to achieve X-ray magnetic tomography and laminography [1-4]. In a first demonstration, we have determined the three-dimensional magnetic nanostructure within the bulk of a soft GdCo2 magnetic micropillar and we have identified the presence of Bloch points of different types [1] as well as three-dimensional structures forming closed vortex loops [3]. Subsequently, we have used the flexibility provided by the laminography geometry to perform time resolved measurements of the magnetization dynamics in a two-phase micrometer size GdCo disk. Therefore, X-ray magnetic three-dimensional imaging, with its recent extension to the soft X-ray regime [5], has now reached sufficient maturity that will enable to unravel complex three-dimensional magnetic structures for a range of magnetic systems.

[1] C. Donnelly et al., Nature 547, 328 (2017)
[2] C. Donnelly et al., New J. Phys. 20, 083009 (2018)
[3] C. Donnelly et al., Nat. Phys. 17, 316 (2021)
[4] C. Donnelly et al., Nat. Nanotechnol. 15, 356 (2020)
[5] K. Witte et al., Nano Letters 20, 1305 (2020)

Invited Talk MA 20.2 Wed 10:00 H37

Magnetic depth profiling with x-ray resonant magnetic reflectivity (XRMR) — •Timo Kuschel — Department of Physics, Bielefeld University, 33615 Bielefeld, Germany

Magnetic depth profiling is one of the important thin-film characterization techniques in today's condensed matter physics and, in particular, in the spintronic research field. The interference of reflected light from the interfaces of a magnetic thin-film system depends on its magnetic state. Thus, the detected reflectivity of typically circularly polarized light provides information on the depth profile of the sample's magnetization. By the use of synchrotron x-rays, this dependence becomes element-selective as long as the absorption energy of a specific chemical element is used as photon energy. Therefore, the analysis of the x-ray resonant magnetic reflectivity (XRMR) separates the individual magnetic depth profiles of different chemical elements [1].

In my contribution, I will introduce this experimental technique and emphasize advantages over standard x-ray magnetic circular dichroism detection [2]. I will discuss the quantitative comparability of XRMR with other experimental techniques [3] and present recent results on the magnetic proximity effect in platinum (Pt), palladium (Pd) and vanadium (V). Finally, I will highlight the cation- and lattice-site sensitivity of XRMR for the study of Fe_3O_4 and its interfaces [4].

[1] S. Macke, E. Goering, J. Phys. Cond. Matter 26, 363201 (2014)
[2] T. Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)
[3] D. Graulich, TK et al., Appl. Phys. Lett. 118, 089901 (2021)
[4] T. Pohlmann, TK et al. Phys. Rev. B. 102, 220411(R) (2020)

Invited Talk MA 20.3 Wed 10:30 H37

Magnetic Bragg Ptychography Studies of Spin Caloritronic — •Dina Carbone[1], Peng Li[2], Stephan Geprägs[3], Rudolf

Gross[3,4], Paul Evans[5], Virginie Chamard[6], and Dan Mannix[7] — [1]MAX IV Laboratory, Lund SE — [2]Diamond Light Source, Didcot UK — [3]Walther-Meißner-Institut, BAdW, Garching DE — [4]Physik-Department, TUM, Garching DE — [5]Univ. of Wisconsin, Madison USA — [6]Institut Fresnel, Marseille FR — [7]ESS, Lund SE & Institut Néel, Grenoble FR

Spin-caloritronics refer to a class of materials in which spin, charge and heat currents can be interconverted. This gives rise to diverse functional properties that offer a great potential towards a new generation of fast and low power consumption electronics. Advances in the design and understanding of future spintronic nanotechnologies require the development of state-of-the-art 3D magnetic characterisation tools.In particular, for crystalline magnetic materials grown at nanoscales, understanding the interdependence of their magnetic properties with crystal structure and strain is crucial.

We have developed a magnetic and structural microscopy based on scanning diffraction, by combining circular polarisation and focussing of the X-ray beam. This has revealed spin texture in prototype spin caloritronics device structures and its relation with crystal orientation down to micron resolution[1]. New results obtained with coherent X-rays, using magnetic Bragg ptychography, push this technique towards a 3D spin microscopy with a resolution of few tens of nm.

[1] Evans et al., Sci. Adv. 6, eaba935, 2020

15 min. break

Invited Talk MA 20.4 Wed 11:15 H37

Imaging the 3D magnetic texture of skyrmion tubes and approaches towards determining their Hall signature — •B. Rellinghaus[1], S. Schneider[1,2], D. Wolf[2], U.K. Rössler[2], M. Schmidt[3], A. Kovács[4], R.E. Dunin-Borkowski[4], D. Pohl[1], A. Thomas[2], D. Krieger[2], B. Büchner[2], and A. Lubk[2] — [1]DCN, cfaed, TU Dresden, Germany — [2]IFW Dresden, Germany — [3]MPI CPfS, Dresden, Germany — [4]FZ Jülich, Germany

Despite the large interest in magnetic skyrmions, their 3D magnetic texture when being extended to skyrmion tubes (SkTs) in volume samples is largely unknown. We have therefore determined the magnetic structure of SkTs using low temperature holographic vector field electron tomography in an external magnetic field [1]. The resulting high-resolution 3D magnetic images reveal deviations from a homogeneous Bloch character, a collapse of the skyrmion texture near surfaces, the coexistence of longitudinal and transverse skyrmion textures, and a correlated axial modulation of the SkTs. Spatially resolved energy density maps calculated from the experimental magnetic induction data prove that these magnetic solitons are stabilized by the Dzyaloshinskii-Moryia interaction, which overcompensates the exchange energy in the centers of the tubes. In order to correlate the occurrence of skyrmionic structures with anomalies in their magneto-transport properties, we have devised a setup for the in-situ measurement of the Hall effect in a transmission electron microscope, first results of which will be highlighted. The work is gratefully supported by DFG within SPP 2137.

[1] D. Wolf et al., Nature Nanotechnology 17 (2021) 250.

Invited Talk MA 20.5 Wed 11:45 H37

Determination of spin chirality and helicity angle by circular dichroism in soft x-ray absorption and resonant elastic scattering — •Gerrit van der Laan — Diamond Light Source, Didcot, UK

The depth profile of the full 3D spin structure of magnetic skyrmions below the surface of bulk Cu2OSeO3 was obtained using the polarization dependence of resonant elastic x-ray scattering (REXS) [AIP Advances 11, 015108 (2021)]. While the bulk spin configuration showed the anticipated Bloch type structure, the skyrmion lattice changes to a Néel twisting (i.e., with a different helicity angle) at the surface within a distance of several hundred nm. The experimental penetration length of the Néel twisting is 7x longer than the theoretical value given by the ratio of J/D. This indicates that apart from the considered spin interactions, i.e., Heisenberg exchange interaction J and Dzyaloshinskii-Moriya interaction D, as well as the Zeeman interaction, other effects must play an important role.

A new rule for the rotational symmetry invariance of the XMCD signal is presented [PRB 104, 094414 (2021)]. A threefold symmetric kagome lattice with negative spin chirality can give a nonzero x-ray magnetic circular dichroism (XMCD), despite a total spin moment of zero. A necessary condition is the existence of an anisotropic XMCD signal for the local magnetic atom. The maximum dichroism is not aligned along the spin direction but depends on the relative orientation of the spin with respect to the atomic orientation.

Invited Talk MA 20.6 Wed 12:15 H37

Identification of complex spin-textures by novel Hall effects — •Juba Bouaziz[1], Hiroshi Ishida[2], Samir Lounis[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]College of Humanities and Sciences, Nihon University, Sakurajosui, Tokyo 156-8550, Japan

Chiral magnetic phases of matter are commonly found in non-centrosymmetric materials. The complex magnetic order is stabilized by the Dzyaloshinskii-Moriya interaction, which promotes topologically non-trivial spin textures such as skyrmions. These entities imprint a characteristic signature on the Hall signal known as the topological Hall effect, allowing their detection employing magneto-transport measurements. In this talk, relying on perturbation theory, we disentangle the multiple contributions to the Hall signal originating from non-collinear magnetism and relativistic effects. We unveil a new contribution, the non-collinear Hall effect (NHE) [1], whose angular form is determined by the magnetic texture, the spin-orbit field of the electrons, and the underlying crystal structure. The NHE together with other components of the Hall resistivity enables the decoding of exotic non-collinear magnetic textures that have been observed in itinerant magnets [1,2]. The impact of the NHE on the Hall signal of several two and three-dimensional spin textures such as magnetic hopfions is examined. [1] J. Bouaziz et al. PRL 126, 147203 (2021), [2] A. Neubauer et al. PRL 102, 186602 (2009).

MA 20.7 Wed 12:45 H37

All-electron holography of hopfions enabled by magneto-induced charges — •Moritz Winterott[1,2] and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

In recent years, far-reaching progress has been made in the field of topological particles. In addition to the well-known skyrmions, three-dimensional topological particles such as hopfions, bobbers and cocoons, are also becoming increasingly interesting. Thereby, a major challenge is the visualisation and recognition of such topological particles hidden in bulk materials. An intuitiv approach is to resolve their magnetic contrast, which is highly non-trivial, especially for antiferromagnetic textures where the overall signals are expected to vanish. Here we demonstrate that the charge carried by such topological objects carries specific dependencies on the misalignement of the magnetic moments, which enable their identification without the need for spin-resolved measurements. We utilize multiple-scattering theory and address the case of ferro- and anti-ferromagnetic hopfions. We identify the achiral and chiral-induced charges. Spin-orbit interaction (SOI) gives rise to the latter in 1^{st} order similarly to the Dzyaloshinskii-Moriya interact and to anisotropic terms, 2^{nd} order in SOI. We proceed to a systematic electron holography of the distinct magneto-induced charges, which provide a direct link to experiments.

MA 21: Terahertz Spintronics

Time: Wednesday 9:30–12:15 Location: H43

MA 21.1 Wed 9:30 H43

Spintronic THz emitters for lightwave-driven scanning tunneling microscopy at MHz repetition rates — •Alkisti Vaitsi[1], Vivien Sleziona[1], Fabian Schulz[2], Luis Enrique Parra Lopez[1], Tom Sebastian Seifert[1,3], Martin Wolf[1], and Melanie Müller[1] — [1]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [2]CIC NanoGUNE BRTA, San Sebastian, Spain — [3]Freie Universität Berlin, Germany

Attaining simultaneous high temporal resolution and signal-to-noise ratio in THz lightwave-driven scanning tunneling microscopy (THz-STM) requires broadband single-cycle THz pulses at high repetition rates and electric field strength. In this context, we report on the operation of ultrabroadband spintronic THz emitters (STE) at MHz repetition rates and pump powers of several Watts. We discuss saturation mechanisms which can reduce THz emission efficiency, such as steady-state and transient heating, limiting the usable fluence at the STE. Furthermore, to maximize the THz field in the STM junction, we analyze and optimize THz propagation into the STM, which due to the ultrabroadband spectrum of the STE requires careful consideration of pump spot sizes in combination with the limitations arising from pump fluence and average pump power density. We present detailed experimental and theoretical analysis of the ideal excitation geometry, which allows STE operation up to 10 W average powers at 2 MHz repetition rate at optimized fluence and THz propagation into the STM.

MA 21.2 Wed 9:45 H43

Investigation of THz electromagnetic response in nanopatterned magnetic heterostructures by current confinement — •Bikash Das Mohapatra[1], Reza Rouzegar[3], Evangelos Papaioannou[1], Tobias Kampfrath[3], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, D-06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Meterialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4, D-06120 Halle, Germany — [3]Department of Physical Chemistry, Fritz Haber Institute, Faradayweg 4-6, 14195 Berlin, Germany

STEs (Spintronic Terahertz Emitters) are novel THz radiation sources. Many studies have demonstrated that the STEs when illuminated with fs-laser pulse, ultrafast spin current is produced which leads to ultrafast transverse charge current by Inverse Spin Hall Effect, resulting in THz electromagnetic pulses. We were able to fabricate THz emitters into arrays of various squares and rectangles of micron or sub-micron size, using Sputter deposition and e-beam lithography. These emitters generate a different emission spectrum than large area reference emitters when irradiated with a fs laser. We propose that the confinement due to small size induces local charge buildup, which leads to additional currents that counterbalance the original charge current due to the Inverse Spin Hall Effect.

MA 21.3 Wed 10:00 H43

Coupling of a local broadband THz emitter to a 2D microresonator — •Christopher Rathje[1], Rieke von Seggern[1], Leon Gräper[1], Jana Kredl[2], Jakob Walowski[2], Markus Münzenberg[2], and Sascha Schäfer[1] — [1]Institut für Physik, Universität Oldenburg — [2]Institut für Physik, Universität Greifswald

Recently, the advent of spintronic terahertz emitters (STE) has introduced a simple approach to generate broadband radiation in the terahertz (THz) spectral domain [1].

In this contribution, we utilize a resonator-grafted STE bilayer illuminated by a focused optical excitation pulse for the generation of a micrometer-scaled broadband THz emitter with a source size far below the THz diffraction limit [2]. The near-field of this localized transient electric dipole is coupled to a bow-tie antenna structure in direct proximity to the emitter. Depending on the position of the excitation focus, we detect the emitted THz time-domain signal in the far-field.

Our results show pronounced changes of the emission characteristics of the excited STE layer for a dipole positioned in the bow-tie gap, demonstrating the capability to tailor the emission spectrum including resonant enhancement of certain frequency components and increase of the overall bandwidth. We discuss the influence of different resonator designs and provide a model of the coupling process supported by numerical simulations. Further results for different isolated resonators and periodically structured metasurfaces are presented.

[1] Seifert et al., Nat. Photonics, 10, 483 (2016)
[2] Rathje et al., manuscript in preparation

MA 21.4 Wed 10:15 H43

Spin pumping in noncollinear antiferromagnets — •Mike Alexander Lund, Akshaykumar Salimath, and Kjetil Magne Dørheim Hals — University of Agder, Norway

The spin pumping and spin-transfer torque mechanisms in antiferromagnets have been theoretically and experimentally investigated in recent years. However, most of these works have concentrated on collinear antiferromagnets, leaving the spin dynamics of the more complex noncollinear antiferromagnets largely unexplored. Apart from a few works on spin-transfer torque, there has been no thorough investigation of the spin pumping process in noncollinear antiferromagnets.

In this talk, I will present our latest work on ac spin pumping in noncollinear antiferromagnets. Starting from an effective action description of the spin system, we derive the Onsager coefficients connecting the spin pumping and spin-transfer torque associated with the dynamics of the SO(3)-valued antiferromagnetic order parameter. Our theory is applied to a kagome antiferromagnet resonantly driven by a uniform external magnetic field. We demonstrate that the reactive (dissipative) spin-transfer torque parameter can be extracted from the pumped ac spin-current in phase (in quadrature) with the driving field. Furthermore, we find that the three spin-wave bands of the kagome antiferromagnet generate spin currents with mutually orthogonal polarization directions. This offers a unique way of controlling the spin orientation of the pumped spin current by exciting different spin-wave modes.

MA 21.5 Wed 10:30 H43

THz spin dynamics in antiferromagnetic Mn2Au — •Yannic Behovits[1,2], Alexander Chekhov[1,2], Stanislav Bodnar[3], Mathias Kläui[3], Martin Jourdan[3], and Tobias Kampfrath[1,2] — [1]Freie Universität Berlin, Insitut für Experimentalphysik, 14195 Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Abteilung Physikalische Chemie, 14195 Berlin, Germany — [3]Johannes-Gutenberg-Universität, Institut für Physik, 55122 Mainz, Germany

In metallic antiferromagnets, intrinsic terahertz (THz) magnons may allow high-speed spin information processing. For CuMnAs and Mn2Au, switching of the Néel vector has been demonstrated by using pulsed electrical currents and free-space THz pulses [1,2]. The switching was attributed to the current-induced Néel spin-orbit torque (NSOT)[3]. However, the underlying spin dynamics have not been observed on picosecond timescales. Here, we employ a THz-pump optical-probe setup to investigate dynamics of antiferromagnetic order induced by NSOT in Mn2Au. We observe a signal proportional to the driving THz field, which is consistent with NSOT-driven spin dynamics both in frequency and symmetry. Our results indicate a strongly damped magnon mode at 0.6 THz. By using a simple model, we can extract material properties and estimate the field strengths required for picosecond rotation of the antiferromagnetic order.

[1] K. Olejnik et al., Sci. Adv., 4(3): p. eaar3566 (2018) [2] S. Yu. Bodnar et al., Nat. Commun., 9(1): p. 348. (2018) [3] J. Zelezny et al., PRL, 113(15): p. 157201 (2014)

MA 21.6 Wed 10:45 H43

Spin-orbit interaction at terahertz rates — •Tom S. Seifert and Tobias Kampfrath — FU Berlin

Spintronics aims at implementing the spin degree of freedom into conventional electronics. To be compatible and competitive, spintronic functionalities thus need to keep pace with the ever-increasing speeds of electronic devices that are foreseen to enter the terahertz range eventually [1]. Therefore, one needs to study fundamental spintronic phenomena at terahertz frequencies. Following this approach, one might not only hope to reveal new physics but also to apply these novel insights in terms of innovative terahertz photonic applications. Here, I will discuss our recent experimental efforts to study a central spintronic effect, the anomalous Hall effect (AHE) [2] in metallic magnets from DC to 40 THz. We find a largely frequency-independent AHE in DyCo5, Gd27Fe73 and Co32Fe68, which we attribute to the large Drude scattering rate in metallic thin films. The gained knowledge could further enhance the efficiency of a novel ultrafast spintronic application, namely the spintronic terahertz source [3].

[1] Walowski, J., et al., J. Appl. Phys. 120 (2016). [2] Seifert, T. S., et al. Adv. Mat. 33 (2021). [3] Seifert, T. S., et al. Appl. Phys. Lett. 120 (2022).

MA 21.7 Wed 11:00 H43

Spin-orbit torque mediated coupling of terahertz light with magnon modes in heavy-metal/ferromagnet heterostructures — •Ruslan Salikhov[1], Igor Ilyakov[1], Lukas Körber[1], Attila Kákay[1], Kilian Lenz[1], Jürgen Fassbender[1], Stefano Bonetti[2,3], Olav Hellwig[1,4], Jürgen Lindner[1], and Sergey Kovalev[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Stockholm University, Stockholm, Sweden — [3]University of Venice, Venice, Italy — [4]Chemnitz University of Technology, Chemnitz, Germany

Nonvolatile and energy-efficient spin-based technologies call for new prospects to realize computation and communication devices that are able to operate at terahertz (THz) frequencies. In particular, the coupling of electro-magnetic radiation to a spin system is a general requirement for future communication units and sensors. Here we propose a layered metallic system, based on a ferromagnetic film sandwiched in between two heavy metals that allows a highly effective coupling of millimeter wavelength THz light to nanometer-wavelength magnon modes. Using single-cycle broadband THz radiation we are able to excite spin-wave modes with a frequency of up to 0.6 THz and a wavelength as short as 6 nm. Our experimental and theoretical studies demonstrate that the coupling originates solely from interfacial spin-orbit torques. These results are of general applicability to magnetic multilayered structures, and offer the perspective of coherent THz excitation of exchange-dominated nanoscopic magnon modes.

MA 21.8 Wed 11:15 H43

Laser-induced charge and spin photocurrents in $BiAg_2$ surface from first-principles — •Theodoros Adamantopoulos[1,2], Maximilian Merte[1,2,3], Frank Freimuth[1,3], Dongwook Go[1,3], Stefan Blügel[1], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The physics of photo-induced effects in interfacial systems is intensively researched these days owing to numerous potential applications. Owing to the complexity of the problem, a comprehensive theoretical picture of photogalvanic effects is still lacking. Here we perform first-principles calculations of laser-induced currents in a $BiAg_2$ surface alloy, which is a well-known material realization of the Rashba model [1, 2]. Our results confirm the emergence of very large in-plane photocurrents as predicted by the Rashba model and establish a benchmark picture of photocurrents at Rashba-like surfaces and interfaces [3]. This work contributes to the study of the role of the interfacial Rashba spin-orbit interaction as a mechanism for the generation of in-plane photocurrents, which are of great interest in the field of ultrafast and terahertz spintronics.

[1] F. Freimuth et al., Phys. Rev. B **103**, 075428 (2021). [2] F. Freimuth et al., Phys. Rev. B **94**, 144432 (2016). [3] T. Adamantopoulos et al., arXiv:2201.07122 (2022).

MA 21.9 Wed 11:30 H43

Transition of laser-induced terahertz spin currents from torque- to conduction-electron-mediated transport — •Oliver Gueckstock[1], Pilar Jimenez-Cavero[1,2], Lukas Nadvornik[1], Irene Lucas[2], Tom S. Seifert[1], Luis Morellon[2], and Tobias Kampfrath[1] — [1]FU Berlin, Germany — [2]Universidad de Zaragoza, Spain

Transport of spin angular momentum is a fundamental operation required for future spin-electronic devices. To be competitive with other information carriers, it is required to push the bandwidth of spin transport to the terahertz (THz) frequency range [1]. Here, we use femtosecond laser pulses to excite prototypical F|N bilayers consisting of a ferrimagnetic metal F and a nonmagnetic metal N [2,3]. Following absorption of the pulse, a spin current in F is launched and converted into a transverse charge current in N, giving rise to the emission of a THz electromagnetic pulse [2]. Depending on the conductivity of F, two driving mechanisms of the spin current can occur: (i) the ultrafast spin Seebeck effect [3] generating magnons and (ii) a spin voltage, generating a spin current carried by conduction electrons [4]. Remarkably, in the half-metallic ferrimagnet Fe3O4, we observe the coexistence of these contributions and disentangle them based on their distinctly different ultrafast dynamics. Our results shed new light on the magnetic structure of this mature material. References: [1] Vedmedenko et al., J. Phys. D: Appl. Phys. 53 453001 (2020), [2] T. Seifert et al., Nat. Phot. 10, 483 (2016), [3] T. Seifert et al., Nat. Comm. 9, Article No: 2899 (2018), [4] R. Rouzegar et al., arXiv:2103.11710 (2021)

MA 21.10 Wed 11:45 H43

Ultrafast spintronic THz emission of thin CoFe/Pt films — •Jannis Bensmann[1], Robert Schneider[1], Mario Fix[2], Steffen Michaelis de Vasconcellos[1], Manfred Albrecht[2], and Rudolf Bratschitsch[1] — [1]University of Münster, Institute of Physics and Center for Nanotechnology, 48149 Münster, Germany — [2]University of Augsburg, Institute of Physics, 86159 Augsburg, Germany

THz radiation has great potential for spectroscopy, security and quality control applications. Recently, ultrafast spintronic THz emitters gained a lot of interest, as they are easy to handle and show high power and broadband emission. In these emitters, an ultrafast laser pulse launches a spin-polarized current from a nanometer-thin magnetic film into a non-magnetic metal layer. Due to the inverse spin Hall effect and the conversion to an ultrafast charge current, THz radiation is created. The THz emission of spintronic emitters can be tuned by the material compositions of the layers.

Here we present our recent results on THz emission spectroscopy of ultrathin Co_xFe_{1-x}/Pt bilayers with varying Co content x. The THz amplitude changes only slightly with x, leading to the conclusion that both Fe and Co have a similar contribution to the THz generation process [1]. Moreover, we were able to boost the THz emission by using multilayer stacks of the mentioned structure.

[1] R. Schneider et al., "Composition-dependent ultrafast THz emission of spintronic CoFe/Pt thin films", Appl. Phys. Lett. 120, 042404 (2022)

MA 21.11 Wed 12:00 H43

Ultrafast coherent THz lattice dynamics coupled to spins in a van der Waals antiferromagnetic flake — •Fabian Mertens[1], David Mönkebüscher[1], Eugenio Coronado[2], Samuel Mañas-Valero[2], Carla Boix-Constant[2], Alberta Bonanni[3], Margherita Matzer[3], Rajdeep Adhikari[3], Alexandra M. Kalashnikova[4], Umut Parlak[1], Davide Bossini[1,5], and Mirko Cinchetti[1] — [1]Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany — [2]Instituto de Ciencia Molecular (ICMol) Universidad de Valencia, Spain — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Austria — [4]alexandra.kalashnikova@gmail.com — [5]Department of Physics and Center for Applied Photonics, University of Konstanz, Germany

We used the setup described in [1] to study the laser driven lattice and spin dynamics of a 380 nm thick flake of the antiferromagnetic van der Waals semiconductor $FePS_3$ as a function of excitation photon energy and sample temperature. We found evidence of a coherent optical lattice mode at a frequency of 3.2 THz. The amplitude of the phononic signal vanishes as the phase transition to the paramagnetic phase occurs, revealing its close connection to the long-range magnetic order. These findings open a pathway towards the coherent manipulation of the magneto-crystalline anisotropy in a van der Waals antiferromagnet, scalable down to thinner flakes.

[1] F. Mertens et al., *Review of Scientific Instruments* **91** (2020)

MA 22: Thin Films: Magnetic Coupling Phenomena / Exchange Bias / Magnetic Anisotropy

Time: Wednesday 9:30–11:45 Location: H47

MA 22.1 Wed 9:30 H47

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

With growing demand for more energy efficient information technology, the utilization of magnons as information carriers entails potential advantages [1]. To successfully develop magnon-based devices, there are several requirements for the applied materials to meet. The insulating ferrimagnet Yttrium Iron Garnet ($Y_3Fe_5O_{12}$, YIG) and related garnets are good candidates with an outstanding low damping and large magnon propagation lengths [1]. Our heterostructures of YIG and Gadolinium Iron Garnet ($Gd_3Fe_5O_{12}$, GIG) were grown by pulsed laser deposition. We observe a ferromagnetic coupling between the Fe sublattices of the two layers, leading to complex magnetic response to external magnetic fields and a nontrivial temperature dependence [2]. We investigate the spin dynamics by broadband ferromagnetic resonance (FMR) experiments. Our observations are corroborated by measurements of SQUID magnetometry, spin Hall magnetoresistance and spin Seebeck effect [2]. [1] A. Chumak et al., Nat. Phys, 11, 453 (2015). [2] S. Becker et al., Phys. Rev. Appl., 16, 014047(2021).

MA 22.2 Wed 9:45 H47

Optical detection of magnon-phonon coupling using μFR-MOKE technique — •Manuel Müller[1,2], Lukas Liensberger[1,2], Mathias Weiler[3], Matthias Althammer[1,2], Rudolf Gross[1,2,4], and Hans Huebl[1,2,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Technische Universität Kaiserslautern, Kaiserslautern, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Magnetoelastic coupling between wave-like excitations of the spin system (spin waves) and the lattice (elastic waves) can result in a hybridization of both modes. This coupling can reach the strong-coupling regime, which is of interest for future (quantum) applications, such as microwave-to-optics transducers and phononic spin valve devices.

We here present an experimental approach to investigate magnon-phonon coupling for the YIG layers in a YIG/GGG/YIG trilayer on an individual basis using the microfocused frequency-resolved magneto-optic Kerr effect(μFR-MOKE) technique [1]. We discuss the magnetization dynamics recorded individually for the top and bottom YIG layer with those acquired using broadband ferromagnetic resonance. This data gives further insight to the involved modes as well as their coupling. As a longterm perspective, we expect that this technique will allow the investigation of microstructures with enhanced coupling rates via their optimized geometry.

[1] L. Liensberger et al., IEEE Magn. Lett. **10**, 5503905 (2019).

MA 22.3 Wed 10:00 H47

Experimental tests of the accuracy of the reflection matrix description in linear magneto-optics — •Carmen Martín Valderrama, Mikel Quintana, and Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain

Magneto-Optical (MO) Kerr Effect (MOKE) techniques are frequently utilized to monitor magnetization M reversal, and even its vector information, in a non-destructive way [1]. The assumption is hereby that the Jones-formalism reflection matrix R, including 1^{st} order MOKE, is given as $R = \begin{pmatrix} r_s & \alpha(m_x)+\gamma(m_z) \\ -\alpha(m_x)+\gamma(m_z) & r_p+\beta(m_y) \end{pmatrix}$, with $m_{x,y,z}$ being the M components in Cartesian coordinates, r_s and r_p as Fresnel coefficients and α, β and γ being MOKE coefficients for longitudinal, transverse and polar effects. Recently, however, there have been reports of linear MOKE that is independent of a sample's magnetization [2]. Thus, it is important to verify the above R expression experimentally, which to our knowledge has not been done rigorously. For this, we utilized a sample with uniform M, which can be precisely rotated by an applied field, thus systematically varying the MOKE coefficients, while monitoring all of them simultaneously by means of General MO Ellipsometry. For the pure in-plane magnetization case, for instance, the α vs. β relation will lead to an ellipse equation, $\alpha^2/\alpha_0^2+\beta^2/\beta_0^2=1$, if R is correct. We have confirmed this behavior experimentally with a very high degree of precision. However, we also discovered deviations from it in cases where samples exhibit MO anisotropy. [1] Appl. Phys. Lett. 71, 965 (1997), [2] Phys. Rev. B 102, 140408(R) (2020)

MA 22.4 Wed 10:15 H47

XMCD investigation on Sm-Co magnetic thin films: strong orbital pinning on Co and the role of Sm — •Damian Günzing[1], Georgia Gkouzia[2], Ruiwen Xie[2], Teresa Wessels[1], Hongbin Zhang[2], Lambert Alff[2], Alpha T. N'Diaye[3], Heiko Wende[1], and Katharina Ollefs[1] — [1]Faculty of Physics, University of Duisburg-Essen — [2]Institute of Materials Science, Technical University of Darmstadt — [3]Advanced Light Source, Lawrence Berkeley National Lab Berkeley

We present the investigation of crystalline Sm-Co thin films manufactured via MBE on an Al_2O_3 substrate without additional buffer layers [1] by soft X-ray magnetic circular dichroism (XMCD). We use XMCD to investigate the element-specific spin and orbital moments of the individual elements, here Sm and Co. Often, with soft X-rays only the first few nm are probed via electron yield detection, leading to significant surface effects. In contrast, here, we use the luminescence of the substrate and are able to study the entire sample over the whole film thickness. We see a surprisingly strong orbital pinning on the Co sites in applied fields up to 2T. From element-specific hysteresis curves we find that the Sm atoms are coupled to Co, but with spectroscopic features saturating different in high fields. We compare the experimental results obtained by XMCD with multiplet calculations using Quanty, which suggest an exchange field present at the Sm site. (Financially supported by the DFG Project-ID 405553726*CRC 270). [1] S. Sharma et al., *ACS Appl. Mater. Interfaces* (2021) 13, 27, 32415-32423

MA 22.5 Wed 10:30 H47

Temperature independent coercivity by means of nanoscale materials design — •Mikel Quintana[1], Adrián Meléndez[1,2], Carmen Martín Valderrama[1], Lorenzo Fallarino[1], and Andreas Berger[1] — [1]CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain — [2]UPV/EHU, E-48940 Bizkaia, Spain

Thin film materials, in which the exchange coupling strength is designed to be depth-dependent, behave at each depth as if their properties were controlled by a "local" Curie temperature T_c^{loc}, down to the 1-2 nm length-scale [1]. This phenomenon enables the control and design of ferromagnetic (FM) magnetization profiles as a function of temperature T. For instance, it allows one to engineer films exhibiting FM exchange-coupling everywhere, but which can split into separate multilayers exhibiting seemingly isolated FM states in certain T-ranges. Here, we present a multilayer system composed by two CoRu films separated by a graded $Co_{1-x(z)}Ru_{x(z)}$ spacer layer with varying Ru concentration x along the depth z of the film. The spacer layer is such that an effective-PM-state thickness dividing two FM films decreases when reducing T. This specific materials design allows us to obtain a coercive field H_c plateau in an extended temperature range, in which H_c changes less than 2% between 150 K and 225 K, while conventional films exhibit a change of 20% in the same T-range. The stable coercivity plateau can be designed at any temperature by means of an adapted $T_c^{loc}(z)$ design, enabling T-independent operation points for technological applications. [1] L. Fallarino et. al., Materials **11**, 251 (2018).

MA 22.6 Wed 10:45 H47

Influence of adhesion layer and sputter gas pressure on structural and magnetic properties of Co/Pt multilayers — •Rico Ehrler[1], Tino Uhlig[1], and Olav Hellwig[1,2] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany

Co/Pt multilayers (MLs) are standard systems for perpendicular anisotropy layered thin films. The use of a specific underlayer, sometimes in combination with additional, very thin adhesion layers, is a common practice to define a crystalline texture for the ML on amorphous substrates. In addition, the sputter gas pressure during deposition can be used to tune the lateral heterogeneity and laminate order, which strongly affect the magnetic behavior of the system. However, the precise interplay between adhesion and sputter gas pressure, especially for the seed layer, is often neglected.

In this context, we will discuss the impact of the underlayers on the structural and magnetic properties of the Co/Pt ML system. We will emphasize the influence of an adhesion layer on the whole system and combine this with a systematic and separate variation of the sputter deposition pressure of Pt seed and Co/Pt ML. Carefully tuning these parameters enables us to exert a high degree of control on the structure of these systems, with characteristics ranging from continuous thin films to isolated grain structures.

MA 22.7 Wed 11:00 H47

Evidence for perpendicular anisotropy gradients in Co thin films on Pt seeds — •Gauravkumar Patel[1], Sven Stienen[1], Ruslan Salikhov[1], Rodolfo Gallardo[2], Lorenzo Fallarino[1,3], Kilian Lenz[1], Jürgen Lindner[1], and Olav Hellwig[1,4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Universidad Tecnica Federico Santa Maria, Valparíso, Chile — [3]CIC energiGUNE BRTA, 01510 Vitoria-Gasteiz, Spain — [4]Chemnitz University of Technology, 09107 Chemnitz

Tailoring the magnetization dynamics and anisotropy in ferromagnetic thin films by different seed layers is of great fundamental and practical importance, e.g., different seed layer materials lead to different microstructure and magnetocrystalline anisotropy energy. We have used Ta and Pt as seed layers for thin Co films and studied their broadband ferromagnetic resonance (FMR) in out-of-plane saturation as a function of Co thickness and determined the respective perpendicular magnetic anisotropy. For Ta seeds, the magnetic anisotropy decreases and shows an inverse thickness dependence. In contrast for Pt seeds the magnetic anisotropy is no longer monotonous with thickness, but shows an initial thickness dependent decrease with a distinct minimum and subsequently a steady increase again. XRD measurements show that for Pt seeds, the Co develops a well-defined hcp texture with a thickness dependent strain relaxation. As a result of this structural evolution for Co on Pt seeds our FMR measurements reveal a strong anisotropy gradient in growth direction for this system.

MA 22.8 Wed 11:15 H47

Magnetization reversal of Co/Pt multilayer systems with weak perpendicular magnetic anisotropy — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Attila Kakay[1], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE

Perpendicular anisotropy thin film systems are well known for their highly periodic magnetic stripe domains. Here we study $[Co(3.0\ nm)/Pt(0.6\ nm)]_X$ multilayers in the regime of transitional in-plane to out-of-plane anisotropy. For this we vary the number of repeats X in order to tune the remanent state from purely in-plane (IP) via tilted stripe domains (tilted), i.e. with significant out-of plane as well as in-plane magnetization component, to fully out-of-plane stripe domains (OOP). Vibrating Sample Magnetometry and Magnetic Force Microscopy are used to investigate three characteristic samples with $X = 6, 11$ and 22, which represent the three above mentioned remanent states, respectively. In contrast to fully in-plane or fully out-of-plane systems experimental data and corresponding micromagnetic simulation of the tilted magnetization regime ($X = 11$) reveals fully reversible field regions as well as distinct points of irreversibility during an external field sweep. This collective reversal behavior seems at first sight somewhat counter intuitive for a macroscopic system and has qualitative similarities with microscopic systems, such as the Stoner Wohlfarth particle and the vortex reversal in an in-plane magnetized disk, which both show as well distinct points of irreversibility.

MA 22.9 Wed 11:30 H47

Magnetic anisotropy and magnetic ordering of transition-metal phosphorus trisulfides — •Tae Yun Kim[1,2] and Cheol-Hwan Park[1,2] — [1]Center for Correlated Electron Systems, Institute for Basic Science, Seoul, Korea — [2]Department of Physics and Astronomy, Seoul National University, Seoul, Korea

Transition-metal phosphorus trisulfides ($TMPS_3$'s) — a family of antiferromagnetic materials to which $FePS_3$, the first discovered two-dimensional magnetic material [1], belongs — have been regarded as an ideal testbed for studying the strong influence of low dimensionality on the existence of magnetic order. We developed anisotropic magnetic models for $TMPS_3$'s from first-principles calculations; the bulk magnetic properties, including the critical temperatures (T_N's), reported from previous experiments were explained very well [2]. Remarkably, it was predicted by applying our magnetic models to the few-layer cases that monolayer $NiPS_3$ exhibits a fairly high T_N, which is in contrast with the conclusion from a recent Raman study that the T_N is largely suppressed in monolayer $NiPS_3$ [3]. We discuss how the degeneracy in the magnetic ground state of monolayer $NiPS_3$ changes significantly its polarized Raman spectra, which provides a reconciliation between our theoretical predictions and the previous experimental results as to the existence of magnetic order in monolayer $NiPS_3$.

[1] J.-U. Lee et al., Nano Lett. 16, 7433 (2016)
[2] T. Y. Kim and C.-H. Park, Nano Lett. 21, 10114 (2021)
[3] K. Kim et al., Nat. Commun. 10, 345 (2019)

MA 23: Magnetic Domain Walls

Time: Wednesday 9:30–10:45 Location: H48

MA 23.1 Wed 9:30 H48

Atomic-scale Insights to Design of High-Performing SmCo based Sintered Permanent Magnets gained by Atom Probe Tomography — •Nikita Polin[1], Stefan Giron[2], Esmaeil Adabifiroozjaei[2], Yangyiwei Yang[2], Alaukik Saxena[1], Oliver Gutfleisch[2], and Baptiste Gault[1,3] — [1]Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf 40237, Germany — [2]Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany — [3]Department of Materials, Royal School of Mines, Imperial College, Prince Consort Road, London SW7 2BP, United Kingdom

Hard disc drives, electric cars and wind turbines - in all these devices permanent magnets are key components to translate mechanical into electrical energy and vice versa. Enhancing performance of permanent magnets thus contributes to energy transition and sustainability. However, practically the performance of permanent magnets only reaches 20% of the possible maximum (called Brown's paradox). This is related to imperfect nanostructure and nanocomposition where atom probe tomography is a suitable tool to gain atomic-scale insights.

In this talk I will present a structural and magnetical investigation of high-end production-grade $Sm_2(Co,Fe,Cu,Zr)_{17}$ permanent magnets which show unusual regions leading to suboptimal performance. Local differences of nano-structure and nano-composition between both regions are studied by atom probe tomography and transmission electron microscopy combined with micromagnetic simulations. These findings suggest design rules for higher performance of Sm_2Co_{17} magnets.

MA 23.2 Wed 9:45 H48

Magneto-Optic Effects and Domain Imaging in EuO/Co Heterostructure — •Seema Seema[1], Henrik Jentgens[1], Paul Rosenberger[1,2], and Martina Müller[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Fakultät Physik, Technische Universität Dortmund, 44221 Dortmund, Germany

Ferromagnetic semiconductors and stable half-metallic ferromagnets with Curie temperatures (Tc) equal to or more than room temperature have been sought for their applications in novel spintronic devices. Europium oxide (EuO) is one of the potential candidates as it possesses strong ferromagnetism of 7 μ_B/Eu atom with a Tc of 69 K. The present work focuses on the magnetization reversal mechanisms and domain images in EuO probed using magneto-optic Kerr microscopy. We aimed to visualize magnetic proximity effect induced changes in magnetic domains and Tc of EuO in a EuO/Metal heterostructure. We synthesized EuO/Co thin film using molecular beam epitaxy and observed differences in the domain saturation behavior as well as the Kerr rotation below Tc. This had been performed by magnetic hysteresis measurement along with simultaneous domain imaging to explore the temperature-dependent magneto-optic effects in EuO in the proximity of Co. This study of magnetic domains in EuO/Co heterostructure can provide insights into achieving room-temperature ferromagnetism in EuO.

MA 23.3 Wed 10:00 H48

Direct observation of bulk-DMI-stabilized Néel-type domain walls in ferrimagnetic rare-earth transition-metal alloys — •Daniel Metternich[1], Riccardo Battistelli[1], Chen Luo[1], Florin Radu[1], Sebastian Wintz[1], Kai Litzius[2], Marcel Möller[3], John Gaida[3], Claus Ropers[3], Manuel Valvidares[4], Pierluigi Gargiani[4], Andrada-Oana Mandru[5], Yaoxuan Feng[5], Hans Josef Hug[5], and Felix Büttner[1] — [1]Helmholtz-Zentrum Berlin, Berlin, Germany — [2]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [3]Georg-August-Universität Göttingen, Göttingen, Germany — [4]ALBA Synchrotron, Barcelona, Spain — [5]Empa, Dübendorf, Switzerland

Since the discovery of bulk DMI within rare-earth transition-metal alloys, the possibility of bulk-DMI-stabilized skyrmions within these materials is an enticing prospect for potential spintronics applications. However, so far, no direct observation of any bulk-DMI-induced chiral spin textures has been reported in this material class.

We present our study on 50-nm-thick DyCo films, which we imaged with transmission X-ray microscopy. We found domain walls and skyrmions, both of which exhibit strong local variations of the chirality up to pure Néel-type. Due to the large film thickness, we attribute the formation of such Néel walls to the presence of significant bulk DMI in our sample. Moreover, we attribute the strong variations of the chirality to lateral changes of the material composition. Lorentz transmission electron microscopy and magnetic force microscopy measurements support our observations.

MA 23.4 Wed 10:15 H48

Electrostatic shaping of magnetic transition regions in La0.7Sr0.3MnO3 — •Qianqian Lan[1], Michael Schnedler[1], Lars Freter[1], Lei Jin[1], Xian-Kui Wei[1], Thibaud Denneulin[1], András Kovács[1], Philipp Ebert[1], Xiaoyan Zhong[2], and Rafal E. Dunin-Borkowski[1] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C 1) and Peter Grünberg Institut (PGI-5), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Department of Materials Science and Engineering, City University of Hong Kong, Kowloon 999077, Hong Kong SAR, People's Republic of China

Ferroelectric domain walls with no rotation of polarization but a change of magnitude of polarization were reported theoretically and experimentally. However, magnetic domain walls with a similar configuration have not been observed experimentally yet to our knowledge. Here, we report an experimental example of a magnetic transition region in La0.7Sr0.3MnO3 films where the magnitude of magnetization gradually changes without rotation even well below Tc. The magnetic and electrostatic characterization reveals that a charge redistribution governs the shape, magnitude, and extent of the corresponding magnetic transition region. The charge redistribution is caused by the equilibrium between carrier diffusion and drift in the electrostatic field at an interface with sharp Mn compositional change in LSMO. Thus, our results demonstrate a case of the electrostatic shaping of magnetic transition regions, which can be expected to be a general property of complex oxide materials.

MA 23.5 Wed 10:30 H48

Strain-controlled Domain Wall injection into nanowires for sensor applications — •Giovanni Masciocchi[1,2], Mouad Fattouhi[3], Andreas Kehlberger[2], Luis López Díaz[3], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Sensitec GmbH, 55130 Mainz, Germany — [3]Department of Applied Physics, Universidad de Salamanca, E-37008 Salamanca, Spain

In this study, we address a well-known challenge in magnetic sensor development, which is the effect of packaging-induced strain on the sensor properties. While previously the field operation window has only been studied in idealized operation conditions, in real devices further external factors such as strain play a role.

In this experimental work, we investigate the injection of a 180° domain wall from a nucleation pad into a nanowire, as typically used for domain wall-based sensors, while straining the device along selected directions. Combining our experimental measurements by Kerr microscopy with micromagnetic simulations, we find that strain, regardless of its direction, increases the domain wall injection field due to the magnetoelastic coupling of the magnetic material. The above-described observations can be explained by an effective strain-induced anisotropy in the device.

We find additionally that a careful material preparation, comprising of an annealing step, can reduce the effective anisotropy caused by the strain in the magnetic layer. With this we show that a device free of magnetostrictive behavior can be achieved.

MA 24: Spin Transport and Orbitronics, Spin-Hall Effects

Time: Wednesday 15:00–18:00 Location: H37

MA 24.1 Wed 15:00 H37

Interplay between ferroelectricity and orbital angular momentum in a two-dimensional SnTe monolayer — •Dimos Chatzichrysafis[1,2], Dongwook Go[1,3], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Physics Department, RWTH-Aachen University, 52062 Aachen, German — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Recent work on Orbitronics has shown that the orbital angular momentum (OAM) plays an important role in transport phenomena. A question that has arisen concerns the exploration of physical mechanisms that can serve as a control knob for the OAM. For that, ferroelectrics comprise the perfect playground. In this talk, we theoretically investigate the interplay between the electrical polarization in 2D SnTe monolayer, the OAM, and its transport effects. Using a tight-binding model we analyze the influence of the ferroelectric polarization on the electronic structure and the OAM texture. Based on this, we show that electric responses of the OAM and its current can be modulated by a ferroelectric order parameter. We believe that our work provides a novel route to controlling the OAM in 2D materials

MA 24.2 Wed 15:15 H37

Spin and orbital transport in rare earth dichalcogenides: The case of EuS2 — •Mahmoud Zeer[1,2], Dongwook Go[1,3], Johanna P Carbone[1,2], Tom G Saunderson[3], Matthias Redies[1,2], Mathias Kläui[3], Jamal Ghabboun[4], Wulfhekel Wulf[3], Stefan Blügel[1,2], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institute and Institute for Advanced Simulation,Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [4]Department of Physics, Bethlehem University, Bethlehem, Palestine

With first principles the electronic, magnetic and transport properties of rare-earth dichalcogenides taking a monolayer of the H-phase EuS_2 as a representative. We predict that the H-phase of the EuS_2 monolayer exhibits a half-metallic behaviour upon doping with a very high magnetic moment. We find the EuS_2 is very sensitive to the value of Coulomb repulsion U. We further predict that the non-trivial electronic structure of EuS_2 directly results in a pronounced anomalous Hall effect with non-trivial band topology. Moreover, while we find that the spin Hall effect closely follows the anomalous Hall effect in the system, the orbital complexity of the system results in a very large orbital Hall effect, whose properties depend very sensitively on the strength of correlations. Our findings thus promote rare earth based dichalcogenides as a promising platform for topological spintronics and orbitronics. Work funded by (MMBF-01DH16027, Zeer et al., arXiv:2201.11017

MA 24.3 Wed 15:30 H37

Differences between magnetotransport properties of doped alloys and doped crystals via ab-initio calculations — •Ondrej Sipr[1,2], Sergey Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics, Czech Academy of Sciences, Praha — [2]New Technologies Research Centre, University of West Bohemia, Plzeň — [3]Ludwig-Maximilians-Universität München

The description of magnetotransport has so far focused on how doping influences clean crystals. However, interest is turning also to substitutional alloys as hosts. Our aim is to investigate to what extent the approaches that proved to be useful for doped crystals can be applied to doped alloys. Calculations are performed for permalloy $Fe_{19}Ni_{81}$ doped with V, Co, Pt, and Au impurities, relying on the Kubo-Bastin equation implemented using the KKR-Green function method.

The dependence of the anomalous Hall and spin Hall conductivities σ_{xy} and σ^z_{xy} on the dopant concentration is nonmonotonic and strongly influenced by the temperature. The fact that the host is disordered and not crystalline has profound influence on how σ_{xy} and σ^z_{xy} depend on the dopant concentration. In particular, σ_{xy} and σ^z_{xy} are not proportional to σ_{xx} for low dopant concentrations. Consequently, the dependence of the anomalous Hall effect and spin Hall effect on the dopant concentration cannot be ascribed unambigously to skew scattering, side-jump scattering, or intrinsic contributions in the same way as it can be done when investigating the effect of doping for a crystalline host, i.e., the standard scaling laws do not apply.

MA 24.4 Wed 15:45 H37

Atomic scale control of spin current transmission at interfaces — •Mohamed Amine Wahada[1], Ersoy Sasioglu[2], Wolfgang Hoppe[3], Xilin Zhou[1], Hakan Denis[1], Reza Rouzegar[4], Tobias Kampfrath[4], Ingrid Mertig[2], Stuart Parkin[1], and Georg Woltersdorf[3] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle(Saale) — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Seckendorff-Platz 1, 06120 Halle, Germany — [3]Institute of Physics, Martin Luther University Halle-Wittenberg, von Danckelmann Platz 3, 06120 Halle, Germany — [4]Department of Physics, Freie Universität Berlin, Arnimalee 14, 14195 Berlin, Germany

Ferromagnet (FM)/heavy metal (HM) bilayers are a fundamental building block in the field of spintronics. Exciting such bilayers with a femtosecond laser pulse can trigger ultrafast spin current (SC) from the FM to the HM layer. In the HM layer, the spin Hall effect converts the SC pulse into a charge current pulse, enabling efficient spintronic THz emitters. Equally as important as the SC generation process is the efficiency of the SC transmission across the FM/HM interface. We show experimentally that the SC transmission is partially suppressed when Ta is interfaced directly with 3d FM materials while this effect is absent when Pt is used as a HM. Based on theoretical calculations, we show that this is due to 3d-5d hybridization effects causing a significant moment reduction at the interface. This effect is expected for all 5d elements with less than half-filled 5d shell. Furthermore, we show that this effect can be eliminated by atomic scale oxide interlayers.

MA 24.5 Wed 16:00 H37

Spin Dynamics in Magnetic Nanojunctions — •Rudolf Smorka[1], Martin Žonda[2], and Michael Thoss[1,3] — [1]Institute of Physics, Albert-Ludwigs-Universität Freiburg — [2]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University Prague — [3]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg

Recent experimental advances of atomic and nanoscale magnetism motivate the study of spin dynamics on ultrafast time scales. In this contribution, we use a quantum-classical hybrid approach to study current-driven magnetization dynamics in systems consisting of tight-binding electrons and localized classical spins. Using this approach, we show that both the electronic structure of the central system and the self-consistent feedback of spin and electron dynamics play a significant role in the dynamical properties of magnetic nano-junctions driven by a dc voltage. Specifically, relaxation dynamics can be enhanced by tuning the dc voltage in resonance with electronic levels of the central system. We analyze this characteristic in nano-junctions containing a single classical Kondo impurity. Furthermore, we investigate current-induced spin-transfer torques in a ferromagnetic spin valve far away from equilibrium and show that electronic levels in the bias window lead to an enhancement of the spin-transfer torques.

MA 24.6 Wed 16:15 H37

Spin and orbital Edelstein effects in a bilayer system with Rashba interaction — •Sergio Leiva[1], Ingrid Mertig[1], and Annika Johansson[2] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics, 06099 Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

The spin Edelstein effect has proved to be a promising phenomenon to generate spin polarization from a charge current in systems without inversion symmetry. In recent years, current-induced orbital magnetization, also called the orbital Edelstein effect, has also been predicted for various systems with broken inversion symmetry [1-7].

In the present work, we calculate the current-induced spin and orbital magnetization for a bilayer system with Rashba interaction, using Boltzmann transport theory with a constant relaxation time. We compare the magnitudes of the spin and orbital Edelstein effects and find that their dependencies on model parameters such as effective mass, spin-orbit coupling, or energy, differ qualitatively, and they can even exhibit opposite signs.

[1] T. Koretsune *et al.*, Phys. Rev. B, **86**, 125207 (2012).
[2] T. Yoda *et al.*, Sci. Rep., **5**, 12024 (2015).
[3] D. Go *et al.*, Sci. Rep. **7**, 46742 (2017)
[4] T. Yoda *et al.*, Nano Lett., **18**, 916 (2018).
[5] L. Salemi *et al.*, Nat. Commun. **10**, 5381 (2019)
[6] D. Hara *et al.*, Phys. Rev. B, **102**, 184404 (2020).
[7] A. Johansson *et al.*, Phys. Rev. Research, **3**, 013275 (2021).

MA 24.7 Wed 16:30 H37

Dynamic and static detection of current-induced spin-orbit magnetic fields — •Lin Chen[1], Matthias Kronseder[2], Dieter Schuh[2], Dominique Bougeard[2], Jaroslav Fabian[2], Dieter Weiss[2], and Christian Back[1] — [1]Department of Physics, Technical University of Munich, Garching bei Munich, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, Regensburg

Quantifying current-induced effective spin-orbit magnetic-fields (SOFs) accurately is a central task for spin-orbitronics. Several methods, e.g., spin-transfer torque ferromagnetic resonance or second harmonic Hall measurements, have been frequently used in the past 10 years. However, most methods show weaknesses, and are not ideal to determine SOFs. Here, we will show two new approaches in this regard. Firstly, we show that it is possible to quantify the SOFs through an analysis of the shape of standing spin-wave patterns, which are probed by time-solved magneto-Kerr microscopy in a laterally confined Fe/GaAs system. This method, which is conceptually different from previous approaches based on lineshape analysis, is phase independent and self-calibrated1. Secondly, we show that one can simultaneously quantify the SOFs and the unidirectional magnetoresistance (UMR) by measuring the second harmonic longitudinal resistance in Co/Pt bilayers2. From these measurements, we can: I) establish a connection between SOFs and UMR, and II) discuss the origin of SOFs. References:1.L. Chen et. al., Phys. Rev. B. 104, 014425 (2021).2.L. Chen et. al., Phys. Rev. B 105, L020406 (2022).

MA 24.8 Wed 16:45 H37

Hidden current-induced spin and orbital torques in bulk Fe_3GeTe_2 from first-principles — •Tom G. Saunderson[1,2], Dongwook Go[1,2], Stefan Blügel[2], Mathias Kläui[1,3], and Yuriy Mokrousov[1,2] — [1]Institute of Physics, JGU, 55099 Mainz, Germany — [2]PGI and IAS, Forschungszentrum Jülich, Germany — [3]Centre for Quantum Spintronics, NTNU, 7491 Trondheim, Norway

Within the field of spintronics, the two dimensional (2D) van der Waals (vdW) material Fe_3GeTe_2 has been in the spotlight in the last few years for exciting characteristics such as nodal line semimetallicity [1], highly efficient spin-orbit torque switching [2] and skyrmion formation [3]. In a recent collaboration [4] we found that spin-orbit torques were observed within the bulk, yet the clean crystal's bilayer system is centrosymmetric. Whilst this leads to overall vanishing spin-orbit torques, strong 'hidden' current-induced torques are harvested by each of the two-dimensional FGT layers separately. We demonstrate, from first principles [5], that an interplay of spin and orbital degrees of freedom has a profound impact on spin-orbit torques in this prototype material. We uncover a drastic difference in the behavior of the conventional spin flux torque and so-called orbital torque as the magnetization is varied resulting in a non-trivial evolution of switching properties. Our findings promote the design of non-equilibrium orbital properties as the guiding mechanism for crafting the properties of spin-orbit torques in layered vdW materials. [1] Nat. Mater. 794, 17 (2018) [2] Nano Lett. 4400, 19 (2019) [3] Nano Lett. 868, 20 (2020) [4] arXiv:2107.09420 [5] arXiv:2204.13052

MA 24.9 Wed 17:00 H37

Modeling spin transport through thin antiferromagnetic insulators — •Niklas Rohling[1] and Roberto E. Troncoso[2,3] —

[1]Department of Physics, University of Konstanz, D-78457 Konstanz — [2]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology (NTNU), NO-7491 Trondheim — [3]Department of Mechanical and Industrial Engineering, NTNU

Experiments have shown spin transport enhancement by a thin antiferromagnetic insulator between a metal and a ferromagnetic insulator [1]. While previous theoretical work [2] was able to reproduce some of the features of those experiments, the interface is typically described by a single parameter only. We consider a model of a thin layer NiO oriented in (111) direction, sandwiched between a metal and a ferromagnetic insulator. We take into account nearest and next-nearest neighbor exchange coupling at the interfaces as well as different magnetic order. We compute the spin current through this system using Fermi's Golden Rule [3]. We find a sensitive dependence on the magnetic configuration as well as on the interface parameters.

[1] Wang et al., Phys. Rev. Lett. 113, 097202 (2014), Phys. Rev. B 91, 220410(R) (2015); Lin et al. Phys. Rev. Lett. 116, 186601 (2016).
[2] Khymyn et al., Phys. Rev. B 93, 224421 (2016); Rezende et al., Phys. Rev. B 93, 054412 (2016).
[3] Bender et al., Phys. Rev. Lett. 108, 246601 (2012).

Financial support by the German Research Foundation (DFG), project No. 417034116 and by the Research Council of Norway through its Centres of Excellence funding scheme, project No. 262633, "QuSpin"

MA 24.10 Wed 17:15 H37

Unified theory of itinerant transport in magnetic platforms based on the slave-boson formalism — •Ricardo Zarzuela[1] and Jairo Sinova[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Institute of Physics Academy of Sciences of the Czech Republic, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

The slave-boson formalism, rooted in the idea that electron hopping in the lattice is accompanied by a backflow of spin excitations, has been widely used in the field of strongly correlated systems to describe metal-insulator transitions and high-Tc superconductivity, to name a few. It is also well suited to explore transport phenomena in spintronic platforms, since the spin exchange with the magnetic background can be easily incorporated into the representation of the electron operators. We show that the slave-boson approach to the Hubbard model for conduction electrons (near half filling) yields an effective low-energy long-wavelength theory for the itinerant transport in magnetic conductors. In particular, an emergent coupling between the magnetization current and the itinerant spin current is responsible for the spin-transfer physics as well as the topological Hall effect observed in magnetic systems. Our slave-boson approach does not require the adiabatic dynamics of the itinerant carriers, so our findings hold for any itinerant spin polarization. We also show that topological defects (e.g., magnetic vortices and magnetic disclinations) mediate both spin-transfer and topological Hall responses in the magnetic medium, which have not been observed experimentally yet.

MA 24.11 Wed 17:30 H37

Non-Collinear Spin Current for Switching of Chiral Magnetic Textures — •Dongwook Go[1,2], Moritz Sallermann[1,3], Fabian R. Lux[2], Stefan Blügel[1], Olena Gomonay[2], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [3]Science Institute and Faculty of Physical Sciences, University of Iceland, VR-III, 107 Reykjavík, Iceland

We propose a concept of non-collinear spin current, whose spin polarization varies in space even in non-magnetic crystals. While it is commonly assumed that the spin polarization of the spin Hall current is uniform, asymmetric local crystal potential generally allows the spin polarization to be non-collinear in space. Based on microscopic considerations we demonstrate that such non-collinear spin Hall currents can be observed for example in layered Kagome Mn_3X (X = Ge, Sn) compounds. Moreover, by referring to atomistic spin dynamics simulations we show that non-collinear spin currents can be used to switch the chiral spin texture of Mn_3X in a deterministic way even in the absence of an external magnetic field. Our theoretical prediction can be readily tested in experiments, which will open a novel route toward electric control of complex spin structures in non-collinear antiferromagnets. Reference: Go *et al.* arXiv:2201.11476

MA 24.12 Wed 17:45 H37

Theory of charge and spin pumping in atomic-scale spiral magnets — Daichi Kurebayashi[1,2], Yizhou Liu[1], •Jan Masell[1,3], and Naoto Nagaosa[1,4] — [1]RIKEN CEMS, Wako, Japan — [2]University of New South Wales, Sydney, Australia — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [4]University of Tokyo, Tokyo, Japan

An Archimedean screw is a classical pump that exploits the equivalence of rotation and translation in helices. Similarly, a spin spiral texture can pump charge and spin by rotating at a frequency. We study these pumping phenomena within a microscopic quantum model by both perturbation theory and numerical simulations. Inside the spiral region, the spin polarization and charge current are linear in the frequency whereas the spin current scales with its square. We find that the charge current is related to the mixed momentum-phason Berry phase which can be viewed as a novel approximate realization of a Thouless pump. It is nearly quantized in spirals with short pitch but decays with 1/lambda for longer pitches unlike true Thouless pumps or Archimedean screws. Moreover, we study the onset of non-adiabaticity, the impact of attached non-magnetic or magnetic contacts, the real-time evolution of the transport observables, and the efects of disorders which, surprisingly, might enhance the spin current but suppress the charge current.[1]

[1] D. Kurebayashi, Y. Liu, J. Masell, and N. Nagaosa, https://doi.org/10.48550/arXiv.2201.05446

MA 25: Ultrafast Magnetization Effects 2

Time: Wednesday 15:00–17:00 Location: H43

MA 25.1 Wed 15:00 H43

Light-induced magnetization dynamics in a ferromagnetic semiconductor — •Jingwen Li[1], Masakazu Matsubara[2], Kristin Kliemt[3], Nazia Kaya[3], Isabel Reiser[3], Cornelius Krellner[3], Johann Kroha[4], Shovon Pal[5], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland — [2]Tohoku University, Japan — [3]Goethe University Frankfurt, Germany — [4]Bonn University, Germany — [5]NISER Bhubaneshwar, India

Ferromagnetic semiconductors are a rare class of materials that can provide a new platform with spin degrees of freedom in electronic and optical devices. All-optical control of the magnetic order is a demanding task, however. As one prototype example, EuO is intriguing for its high Curie Temperature ($T_c = 69\,K$) induced by the indirect exchange interactions between the Eu atoms. The interactions can be enhanced by photo-doping in an ultrafast non-thermal way, strengthing the ferromagnetic order. This was verified in the ferromagnetic phase of the material [1], but evidence for an enhancement of the magnetic order around or above T_c is still lacking. In this contribution, we show the photo-induced presence of magnetic ordering even at temperatures higher than T_c by making use of the temperature-dependent spectral shift accompanying the magnetically ordered states using optical pump-probe spectroscopy. In optical reflection experiments, we observe two distinct types of ultrafast processes related to the optically driven magnetic order that show different relaxation rates. Our results provide clear evidence of short-range magnetic order above T_c, originating from the so-called exciton magnetic polarons.

MA 25.2 Wed 15:15 H43

Non-thermal optical generation of non-collinear magnetic phase in insulating ferrimagnetic iron garnet — •Sergii Parchenko[1], Antoni Frej[2], Hiroki Ueda[1], Robert Carley[1], Laurent Mercadier[1], Natalia Gerasimova[1], Giuseppe Mercurio[1], Justine Schlappa[1], Alexander Yaroslavtsev[1], Naman Agarwal[1], Andreas Scherz[1], Andrzej Stupakiewicz[2], and Urs Sergii[3] — [1]European Free Electron Laser, Schenefeld, Germany — [2]University of Bialystok, Bialystok, Poland — [3]Paul Scherrer Institute, Villigen, Switzerland

For a long time, nearly all experimental examples of magnetic switching by femtosecond pulses were demonstrated on metals and relied on mechanisms directly related to laser-induced heating close to the Curie temperature. The discovery of all-optical magnetization switching in Co: doped iron garnets via photomagnetic effect opened a new approach for magnetization control and raised a question about the microscopic nature of photo-magnetic spin dynamics. In order to reveal the magnetization dynamic of individual sublattices after excitation with NIR ultrashort laser pulses, we implement time-resolved XMCD techniques in a soft x-ray regime. We found that the dynamics of two antiferromagnetically coupled magnetic moments are drastically different during the first picosecond after the NIR excitation. The dynamics of Fe in tetrahedral oxygen surroundings showed a fast component lasting for about a picosecond. We state that the observed photoinduced noncolinear magnetic phase might be crucial for the all-optical magnetization switching in this material.

MA 25.3 Wed 15:30 H43

Spin-dependent carrier dynamics in antiferromagnetic model systems — •Marius Weber[1], Kai Leckron[1], Benjamin Stadtmüller[1,2], Baerbel Rethfeld[1], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern — [2]Institute of Physics, Johannes Gutenberg University Mainz

The Elliot-Yafet mechanism for the relaxation of an electronic spin polarization was originally derived for the electron-phonon scattering in degenerate bands in semiconductors [1]. Recently, we investigated how the concept of Elliott-Yafet spin-flip scattering can be applied to a microscopic treatment of carrier scattering in ferromagnetic metals including a ferromagnetic splitting and spin-orbit coupling [2].

Here we use the microscopic approach of [2], which utilizes the equation of motion formalism for the k-resolved reduced spin density matrix, to calculate the electronic dynamics in antiferromagnets such as the minimal model system discussed in [3]. The band structure of this model is anisotropic with two twofold degenerate bands and pronounced spin mixing. We investigate the spin-resolved electronic dynamics for different scenarios of spin-polarized anisotropic excitation, such as spin injection and k-selective spin flips.

[1] R. J. Elliott; Physical Review 96, 266, (1954).
[2] K. Leckron et al.; Phys. Rev. B 96, 140408 (2017).
[3] L. Smejkal et al.; Phys. Status Solidi RRL, 11 (2017).

MA 25.4 Wed 15:45 H43

Spectroscopic Analysis of the Ultrafast Non-Equilibrium Dynamics in Nickel at the European X-Ray Free-Electron Laser — •T. Lojewski[1], M. F. Elhanoty[2], N. Rothenbach[1], Y. Kvashnin[2], L. Le Guyader[3], B. Van Kuiken[3], R. Carley[3], J. Schlappa[3], R. Gort[3], G. Mercurio[3], A. Yaroslavtsev[2,3], N. Gerasimova[3], M. Teichmann[3], L. Mercadier[3], R. Y. Engel[4], P. Miedema[4], L. Spieker[1], F. Döring[5], B. Rösner[5], F. De Groot[6], P. Thunström[2], O. Grånäs[2], J. Jönsson[2], C. Lambert[7], I. Pronin[8], J. Rezvani[9], M. Pace[10], C. Boeglin[10], C. Stamm[7,11], M. Beye[4], C. David[5], O. Eriksson[2], A. Scherz[3], U. Bovensiepen[1], H. Wende[1], K. Ollefs[1], and A. Eschenlohr[1] — [1]Univ. Duisburg-Essen — [2]Uppsala Univ. — [3]European XFEL — [4]DESY — [5]PSI — [6]Utrecht Univ. — [7]ETH Zürich — [8]ITMO Univ. — [9]INFN — [10]Univ. of Strasbourg — [11]FHNW

X-ray absorption spectroscopy is a powerful technique to investigate non-equilibrium dynamics combining a sensitivity to electron and lattice dynamics with element specificity. We report the time-resolved, spectroscopic analysis of Nickel-metal $L_{2,3}$-edge X-ray absorption spectra and their pump-induced changes measured at the SCS instrument of the European XFEL with unprecedented energy resolution and dynamic range. In addition, *ab initio* DFT and TD-DFT calculations connect the pump-induced changes to modifications of the electronic DOS. We find pump-induced redshifts and reduced absorption at the $L_{2,3}$-edges, which we explain by a loss of magnetic moment, changes in the electronic correlations and redistribution of electron population.

MA 25.5 Wed 16:00 H43

Indirect optical manipulation of the antiferromagnetic order of insulating NiO by ultrafast interfacial energy transfer — •Stephan Wust[1], Christopher Seibel[1], Hendrik Meer[2], Paul Herrgen[1], Christin Schmitt[2], Lorenzo Baldrati[2], Rafael Ramos[3], Takashi Kikkawa[4], Eiji Saitoh[4], Olena Gomonay[2], Jairo Sinova[2], Yuriy Mokrousov[2], Hans Christian Schneider[1], Mathias Kläui[2], Baerbel Rethfeld[1], Benjamin Stadtmüller[1,2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany — [3]CIQUS, Departamento de Química-Física, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [4]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan

Antiferromagnets are promising candidates for improved future spintronic devices in terms of robustness and speed. Here, we report the ultrafast, (sub)picosecond reduction of the antiferromagnetic order of the insulating NiO thin film in a Pt/NiO bilayer. This reduction of the antiferromagnetic order is not present in pure NiO thin films after a strong optical excitation. This ultrafast phenomenon is attributed to an ultrafast and highly efficient energy transfer from the optically excited electron system of the Pt layer into the NiO spin system. We propose that this energy transfer is mediated by a stochastic exchange scattering of hot Pt electrons at the Pt/NiO interface.

MA 25.6 Wed 16:15 H43

Heat-conserving three-temperature model for ultrafast demagnetisation simulations of nickel and iron — •Maryna Pankratova[1], Ivan Miranda[1], Danny Thonig[2,1], Manuel Pereiro[1], Erik Sjöqvist[1], Anna Delin[3], Olle Eriksson[1,2], and Anders Bergman[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]School of Science and Technology, Örebro University, SE-701 82, Örebro, Sweden — [3]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, AlbaNova University Center, SE-10691 Stockholm, Sweden

In this work, we introduce a new heat-conserving three temperature model (HC3TM) for calculations of spin, electron, and lattice temperatures during ultrafast magnetisation dynamics simulations.

The proposed HC3TM has several advantages in comparison with the three-temperature model (3TM), proposed by Beurepaire. It reduces the reliance on heat transfer parameters, such as electron-spin, electron-lattice, and spin-lattice. These parameters are often hard to estimate which impedes the comparison with experimental data.

We apply HC3TM for the simulations of ultrafast demagnetisation of nickel and iron and compare the results with 3TM. HC3TM gives a demagnetisation rate during the first picoseconds after the absorption of a laser pulse which is in line with experiments. Overall, the proposed HC3TM reproduces experimental observations for nickel and iron better than most existing 3TM while it reduces the number of required parameters.

MA 25.7 Wed 16:30 H43

X-ray absorption spectroscopy on spin-crossover molecules — •Lea Spieker[1], Tobias Lojewski[1], Carolin Schmitz-Antoniak[2], Florin Radu[3], Torsten Kachel[3], Laurent Mercadier[4], Andreas Scherz[4], Loïc le Guyader[4], Martin Teichmann[4], Robert Carley[4], Giuseppe Mercurio[4], Natalia Gerasimova[4], Benjamin van Kuiken[4], Cammille Carinan[4], David Hickin[4], Damian Günzing[1], Soma Salamon[1], Gérald Kämmerer[1], Peter Kratzer[1], Klaus Sokolowski-Tinten[1], Manuel Gruber[1], Andrea Eschenlohr[1], Katharina Ollefs[1], Senthil Kumar Kuppusamy[5], Mario Ruben[5,6], Uwe Bovensiepen[1], and Heiko Wende[1] — [1]University of Duisburg-Essen and CENIDE — [2]University of Applied Science Wildau — [3]Helmholtz Center Berlin — [4]European XFEL — [5]Karlsruhe Institute of Technology — [6]CNRS-University of Strasbourg

Spin-crossover molecules with abrupt spin-state switching in the room temperature regime are of great interest for future device applications. With X-ray absorption spectroscopy (XAS), it is possible to investigate their temperature-, visible light-, or X-ray induced spin-state switching. Recently, we performed static, temperature-dependent XAS measurements to study X-ray induced switching behavior as well as ultrafast time-resolved XAS measurements to analyze light-induced spin-state switching. We acknowledge European XFEL in Schenefeld, Germany, for the provision of X-ray free-electron laser beamtime at the SCS instrument. The financial support by CRC 1242 Projects A05, A07, B02, and C01 (Project-ID 278162697) is gratefully acknowledged.

MA 25.8 Wed 16:45 H43

Ultrafast magnetization dynamics in heterogeneous material compositions — •Sebastian T. Weber[1], Christopher Seibel[1], Marius Weber[1], Martin Stiehl[1], Sanjay Ashok[1], Simon Häuser[1], Martin Aeschlimann[1], Hans Christian

Schneider[1], Benjamin Stadtmüller[1,2], and Baerbel Rethfeld[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern — [2]Institute of Physics, Johannes Gutenberg University Mainz

Ultrafast magnetization dynamics plays a key role in the development of spintronic devices. The dynamics are influenced by the composition of material systems as well as the wavelength of the optical excitation. The latter can create spatially inhomogeneous excitation profiles in thick nickel films [1,2] or Ni|Au heterostructures [3].

In this contribution, we compare results of the thermodynamic μT-model with kinetic Boltzmann calculations and MOKE-measurements to investigate the influence of the wavelength on magnetization dynamics in different compositions. Our results show that laser and material parameters can enhance or hinder the interplay of relaxation processes, leading to different laser-induced magnetization dynamics.

[1] U. Bierbrauer *et al.*, JOP: Cond. Mat. 29, 244002 (2017)
[2] S. Ashok *et al.*, Appl. Phys. Lett. 120, 142402 (2022)
[3] C. Seibel *et al.*, arXiv:2112.04780 (2021)

MA 26: Molecular Magnetism

Time: Wednesday 15:00–16:00 Location: H48

MA 26.1 Wed 15:00 H48

Density functional theory studies of a Fe(II) spin-crossover complex — •Gerald Kämmerer and Peter Kratzer — University Duisburg-Essen, Duisburg, Germany

We investigate the spin-state switching of a Fe(II) spin-crossover complex ($[Fe(1-bpp-COOC_2H_5)_2](BF_4)_2CH_3CN$) from a diamagnetic low-spin (S=0) to a paramagnetic high-spin (S=2) state in the framework of density functional theory (DFT). The calculations were carried out with FHI-Aims code using PBE and B3LYP functionals. Due to the switching, the bond length Fe-N increases by up to 20%. In addition, calculations for Raman spectra were done for both spin-states and compared to temperature-dependent Raman measurements. This allows us the analysis of a unique fingerprint of the molecular bondings as well as the assignment of specific Raman modes. The financial support by DFG within CRC 1242 (*Project B 02*) and computation time on the MagnitUDE supercomputer system are gratefully acknowledged.

MA 26.2 Wed 15:15 H48

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

The discovery of slow relaxation and quantum tunnelling of the magnetization in the single molecule magnets (SMMs) two decades ago has led to a flurry of research towards improving their magnetic properties. This class of molecules has been expanded to heterometallic clusters incorporating transition metal and rare earth ions. The $4f$ ions are of interest because of their large angular momenta and magnetic anisotropies, but exactly the latter feature leads to unexpected challenges in the numerical analysis of experimental susceptibility and magnetization curves. Inelastic neutron scattering (INS) experiments were performed on the time-of-flight disk-chopper spectrometers IN5 and IN6 at ILL on the SMMs Mn_2Ln_2-squares with Ln = Y, Tb, Ho, Dy, and the M_2Ln_2-butterflies with M = Fe, Al and Ln = Dy, Er. High quality INS data were recorded, even for the Dy containing species besides the strong neutron absorbtion of this ions. The analysis and interpretation of the INS data, and of magnetic data, by means of a linked fit approach and using effective models is presented.

MA 26.3 Wed 15:30 H48

Study of VOPc/TiOPc layers on Ag(100) using X-ray absorption spectroscopy — •Jaehyun Lee[1,2], Stefano Reale[1,2], Kyungju Noh[1,2], Luciano Colazzo[1], Denis Krylov[1], Christoph Wolf[1], Andrin Doll[3], Andreas Heinrich[1,2], Yujeong Bae[1,2], and Fabio Donati[1,2] — [1]Center for Quantum Nanoscience — [2]Ewha Womans University, Seoul, Republic of Korea — [3]Swiss Light Source, Paul Scherrer Institut (PSI), Villigen Switzerland

Vanadyl Phthalocyanine (VOPc) shows spin 1/2 and long coherence time of almost 1 microseconds up to room temperature [M. Atzori et al., J. Am. Chem.Soc. 138, 2154 (2016)]. Investigating the orbital splitting when absorbed on a surface and the interactions between the molecular spin and the supporting substrate is crucial to optimize their quantum coherence properties. Here, we use x-ray absorption spectroscopy to investigate the spin properties of VOPc on Ag(100) and on TiOPc/Ag(100). To interpret our data, we simulate x-ray spectra combining machine learning with multiplet calculations. We find that the interaction with the metal surface changes the orbital structure of VOPc when directly on the Ag(100). Decoupling from the metal using a TiOPc layer is sufficient to restore the spin and orbital structure of the free standing VOPc, which shows no changes upon annealing up to 450K. This robust molecular spin architecture shows the potential in quantum computing technology.

MA 26.4 Wed 15:45 H48

High-frequency EPR studies on monomeric 4f complexes — Lena Spillecke, Changhyun Koo, and •Rüdiger Klingeler — Kirchhoff Institute for Physics, Heidelberg University, Germany

Tuning of magnetic anisotropy by appropriate design of crystal fields in 4f monomeric complexes is guided by experimental determination of relevant parameters – here by high-frequency electron paramagnetic resonance (HF-EPR) studies – and by numerical results. Our recent study on pentagonal-bipyramidal Er(III) [1] complexes is motivated by a reported difference in relaxation behavior [2]. Evaluating the data in a $S = 1/2$ pseudo spin approximation for each Kramers doublet (KD) results in the precise determination of the crystal field splitting energies and effective g-values of the three lowest KDs. Relaxation behaviour is directly traced back to changes in electronic structure, induced by the crystal field and are attributed to a pronounced non-axiality of the ground-state g-tensor promoting a fast QTM magnetic relaxation. Another confirmation of a guided approach is provided by recent data on a set of [Ln(III)L12]-complexes (Ln = Dy, Tb) involving tetradentate ligands [3] as well as by studies of a novel nonadentate bispidine-based ligand where the experimentally determined relaxation barrier of 46 cm^{-1} is rather modest but in excellent agreement with that predicted by ab-initio calculations [4].

[1]L. Spillecke et al., Dalton Transactions 50, 18143 (2021) [2]T.A. Bazhenova et al., Molecules 26, 6908 (2021) [3]P. Comba et al., Chemistry-Eur. J. 24, 5319 (2018) [4]P. Cieslik et al., J of Inorg. Gen. Chem. (Z. Anorg. Allg. Chem.) 647, 843 (2021)

MA 27: Skyrmions 2 (joint session MA/KFM)

Time: Thursday 9:30–12:45 Location: H37

MA 27.1 Thu 9:30 H37

Complementary investigations of magnetic textures in the antiskyrmion compound $Mn_{1.4}$PtSn with REXS and LTEM

— M. Winter[1,2,3,4], M. Rahn[4], D. Wolf[3], S. Schneider[2], M. Valvidares[5], •C. Shekar[1], P. Vir[1], B. Achinuq[6], H. Popescu[7], N. Jaouen[7], G. Van der Laan[8], T. Hesjedal[6], B. Rellinghaus[2], and C. Felser[1] — [1]MPI CPfS, Dresden, Germany — [2]DCN, TU Dresden, Germany — [3]IFW Dresden, Germany — [4]IFMP, TU Dresden, Germany — [5]ALBA Synchrotron, Barcelona, Spain — [6]Clarendon Laboratory, University of Oxford, UK — [7]Synchrotron SOLEIL, Saint-Aubin, France — [8]Diamond Light Source, UK

The Heusler compound $Mn_{1.4}$PtSn is known to host multiple non trivial magnetic textures like antiskyrmions (aSks). It's phase diagram depends not only on temperature and sample shape, but also on strength and orientation of an external magnetic field as well as on the history of its application. In order to better understand the formation of aSks, we have conducted complementary experiments of resonant elastic x-ray scattering (REXS) and Lorentz transmission electron microscopy (LTEM) on an identical lamella of $Mn_{1.4}$PtSn. Our complementary approach allows for the first time to directly relate the REXS patterns to the underlying magnetic phase as determined from LTEM. Along this approach, LTEM has proven an ideal pre-characterization tool to navigate the high-dimensional parameter space and subsequently take advantage of the better control of magnetic field directions, temperature as well as of energy resolved measurements as provided by REXS.
Part of this work is gratefully supported by DFG within SPP 2137.

MA 27.2 Thu 9:45 H37

Doping control of magnetic anisotropy for stable antiskyrmion formation in schreibersite (Fe,Ni)3P with S4 symmetry

— Kosuke Karube[1], Licong Peng[1], •Jan Masell[1,2], Mamoun Hemmida[3], Hans-Albrecht Krug von Nidda[3], István Kézsmárki[3], Xiuzhen Yu[1], Yoshinori Tokura[1,4], and Yasujiro Taguchi[1] — [1]RIKEN CEMS, Wako, Japan — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [3]University of Augsburg, Augsburg, Germany — [4]University of Tokyo, Tokyo, Japan

Recently, growing attention has also been paid to antiskyrmions emerging in non-centrosymmetric magnets with D2d or S4 symmetry. [1] In these magnets, complex interplay among anisotropic Dzyaloshinskii-Moriya interaction, uniaxial magnetic anisotropy, and magnetic dipolar interactions generates a variety of magnetic structures. We control the uniaxial magnetic anisotropy of schreibersite (Fe,Ni)3P with S4 symmetry by doping and investigate its impact on the stability of antiskyrmions. With magnetometry, supported by ferromagnetic resonance spectroscopy, Lorentz transmission electron microscopy, and micromagnetic simulations, we quantitatively analyze the stability of antiskyrmion as functions of uniaxial anisotropy and demagnetization energy, and demonstrate that subtle balance between them is necessary to stabilize antiskyrmions.

[1] K. Karube, L. C. Peng, J. Masell, X. Z. Yu, F. Kagawa, Y. Tokura, and Y. Taguchi, Nat. Mater. 20, 335-340 (2021) [2] The authors, Adv. Mater. 34 (11), 2108770 (2022)

MA 27.3 Thu 10:00 H37

Magnetic and Morphological Phases in the 2D van der Waals Magnet FexGeTe2

— •Kai Litzius[1], Max Birch[1,5], Lukas Powalla[2,3,5], Sebastian Wintz[1], Fabian Alten[1], Michael Miller[1], Markus Weigand[4], Klaus Kern[2,3], Marko Burghard[2], and Gisela Schütz[1] — [1]Max-Planck-Institute for Intelligent Systems, 70569 Stuttgart, Germany — [2]Max-Planck-Institute for Solid State Research, 70569 Stuttgart, Germany — [3]Institut de Physique, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland — [4]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany — [5]These authors contributed equally to the work

Recently, observations of magnetic skyrmions in 2-dimensional (2D) itinerant ferromagnets opened many possibilities for technological implementation of 2D van der Waals structures in spintronics. However, the stability of the different magnetic states and morphological phases in FexGeTe2 remains an unresolved issue. In this work, we utilize real-space imaging to determine magnetic phase diagrams of exfoliated FexGeTe2 films. Our findings show besides complex, history-dependent magnetization states also that changes in the crystalline structure significantly alter the magnetic behavior. Ultimately, the choice of material and a proper nucleation mechanism result in the stabilization of a variety of (meta-) stable magnetic configurations, including skyrmions. These findings open novel perspectives for designing van der Waal heterostructure-based devices incorporating topological spin textures.

MA 27.4 Thu 10:15 H37

Antiskyrmions in B20-type FeGe

— •Nikolai S. Kiselev[1], Fengshan Zheng[2,3], Luyan Yang[2], Vladyslav M. Kuchkin[1], Filipp N. Rybakov[4,5], Stefan Blügel[1], and Rafal E. Nikolai[2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Le Brandst. 1 — [3]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 — [4]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden — [5]Department of Physics, KTH-Royal Institute of Technology, SE-10691 Stockholm, Sweden

We report the highly reproducible observations of statically stable antiskyrmion [1] – skyrmion antiparticle in thin plates of B20-type FeGe chiral magnet where only skyrmions were observed earlier. Using Lorents TEM and electron holography, we showed that skyrmions and antiskyrmions could coexist in a wide range of fields and temperatures. These findings are entirely consistent with micromagnetic simulations and prior theoretical studies of two-dimensional systems [2]. The mechanism of antiskyrmion stability, nucleation, and annihilation with ordinary skyrmions is discussed in detail.

[1] F. Zheng et al., Nat. Phys. (2022) accepted.
[2] V. M. Kuchkin, N. S. Kiselev, Phys. Rev. B 101, 064408 (2020).

MA 27.5 Thu 10:30 H37

Asymmetric magnetization reversal in perpendicularly magnetized micro stripes induced by exchange-bias effect and Dzyaloshinskii-Moriya interaction

— •Sapida Akhundzada[1], Piotr Kuświk[2], Christian Janzen[1], Arno Ehresmann[1], and Michael Vogel[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany — [2]Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland

In a systematic study, the magnetization reversal in exchange-biased Ti/Au/Co/NiO/Au micro stripes with perpendicular magnetic anisotropy is characterized using high-resolution magneto-optical Kerr microscopy. Thereby, the remagnetization process is observed to be asymmetric with respect to the two branches of the hysteresis loop, being quantified as a higher nucleation density formed along one field branch with decreasing structure width. Additionally, a local asymmetry in the domain nucleation and domain wall movement within the stripe geometry is observed. The influence of the exchange bias effect and the Dzyaloshinskii-Moriya interaction is investigated by field-cooling and the application of additional in-plane magnetic fields during the magnetization reversal process. XMCD and XMLD experiments reveal the corresponding domain texture in the ferromagnetic and antiferromagnetic layers. These experiments show how the interplay between chiral Dzyaloshinskii-Moriya interaction and the unidirectional anisotropy modify the magnetic domain texture and the resulting magnetization reversal in microstructures.

MA 27.6 Thu 10:45 H37

Magnetic skyrmion braids

— •Nikolai S. Kiselev[1], Fengshan Zheng[2], Filipp N. Rybakov[3], Dongsheng Song[2], András Kovács[2], Haifeng Du[4], Stefan Blügel[1], and Rafal E. Dunin-Borkowski[2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [3]Department of Physics, KTH-Royal Institute of Technology, Stockholm, SE-10691 Sweden — [4]The Anhui Key Laboratory of Condensed Matter Physics at Extreme Conditions, High Magnetic Field Laboratory, Chinese Academy of Science (CAS), Hefei, Anhui Province 230031, China

In cubic chiral magnets, the magnetization of skyrmions resembles a string-like or filamentary texture. Skyrmion strings are naturally expected to interwind and form complex three-dimensional superstructures by analogy to elastic strings. We found that skyrmion strings in cubic crystals of chiral magnets can form braids – statically stable configurations where skyrmion strings wind around one another [1]. This finding is confirmed by direct observations of skyrmion braids in B20-type FeGe using transmission electron microscopy. The theoretical analysis predicts that the discovered phenomenon is general for a wide family of chiral magnets and can be observed in thick plates and bulk crystals.

[1] F. Zheng, et al., Nature Commun. 12, 5316 (2021).

MA 27.7 Thu 11:00 H37

Tunable ellipticity of Bloch skyrmions in antiskyrmion-hosting materials — Sebastian Schneider[1,2], •Jan Masell[1,3], Fehmi S. Yasin[1], Licong Peng[1], Kosuke Karube[1], Yasujiro Taguchi[1], Darius Pohl[2], Bernd Rellinghaus[2], Yoshinori Tokura[1,4], and Xiuzhen Yu[1] — [1]RIKEN CEMS, Wako, Japan — [2]TU Dresden, Dresden, Germany — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [4]University of Tokyo, Tokyo, Japan

Magnetic skyrmions are usually stabilized and studied in materials with isotropic Dzyaloshinskii-Moriya interaction (DMI). In materials with D2d or S4 symmetry, however, the sign of the DMI is exactly opposite in two orthogonal directions such that it favors antiskyrmions instead of skyrmions. [1,2] Yet, uniaxial anisotropy and dipolar interactions can also help stabilizing skyrmions in such materials which, as a consequence of the anisotropic DMI, are rendered elliptical. We quantify the elliptical distortion of skyrmions in an S4 symmetric material as function of magnetic field and temperature using LTEM holography. Our micromagnetic simulations and simple analytical modelling explain the experimentally observed behavior and provide a technique to quantitatively estimate the DMI.

[1] K. Karube, L. C. Peng, J. Masell, X. Z. Yu, F. Kagawa, Y. Tokura, and Y. Taguchi, Nat. Mater. 20, 335-340 (2021) [2] K. Karube, L. C. Peng, J. Masell, M. Hemmida, H.-A. Krug von Nidda, I. Kézsmárki, X. Z. Yu, Y. Tokura, and Y. Taguchi, Adv. Mater. 34 (11), 2108770 (2022) [3] In preparation.

MA 27.8 Thu 11:15 H37

Long-range non-collinearity and spin reorientation in the centrosymmetric hexagonal magnet NiMnGa — •Parul Devi[1], Sanjay Singh[2], Thomas Hermannsdörfer[1], and Joachim Wosnitza[1,3] — [1]Dresden High Magnetic Field Laboratory, HZDR, Germany — [2]Institut für Festkörper und Materialphysik, TU Dresden, Germany — [3]School of Materials Science and Technology, Indian Institute of Technology (BHU), Varanasi-221005, India

The recent discovery of biskyrmions and skyrmions in globally centrosymmetric crystals has raised questions about the role of the Dzyaloshinskii-Moriya interactions (DMI) in causing the topologically stable spin vortex textures, since DMI vanishes in such crystal structures. Here, we present a detailed crystal and magnetic structure investigation of the non-collinear hexagonal magnetic material NiMnGa exhibiting biskyrmions [1]. We show an investigation on the nature of the phase transitions, evidence of magnetoelastic coupling and anomalous thermal expansion in hexagonal, centrosymmetric NiMnGa using combined studies of magnetization and high-resolution synchrotron x-ray powder diffraction data. Magnetization data exhibits spin reorientation transition * 200 K. By means of powder neutron diffraction data, we investigate the change of the magnetic structure in NiMnGa. This study will help to understand the origin of biskyrmions in the absence of Dzyaloshinskii-Moriya interaction in magnetic materials.

[1] Yu et al., Nat. Comm. 5, 3198 (2014).

MA 27.9 Thu 11:30 H37

Zero-field skyrmionic states and in-field edge-skyrmions induced by boundary tuning — •Jonas Spethmann, Elena Y. Vedmedenko, Roland Wiesendanger, André Kubetzka, and Kirsten von Bergmann — Universität Hamburg, Hamburg, Germany

When magnetic skyrmions are moved via currents, they do not strictly travel along the path of the current, instead their motion also gains a transverse component. This so-called skyrmion Hall effect can be detrimental in potential skyrmion devices because it drives skyrmions towards the edge of their hosting material where they face potential annihilation. To mitigate this problem it was proposed to create a potential well within the skyrmion hosting material and thereby guide the skyrmions along a desired pathway[1]. Here we have experimentally modified a skyrmion model system–an atomic Pd/Fe bilayer on Ir(111)[2]–by growing a self-assembled ferromagnetic Co/Fe bilayer adjacent to it. Employing spin-polarized scanning tunneling microscopy, we demonstrate that this ferromagnetic rim has an immediate effect on the spin spiral ground state of the Pd/Fe bilayer, stabilizes skyrmions and target states in zero field and prevents skyrmion annihilation at the film edge. Furthermore we show that in applied magnetic fields the Co/Fe gives rise to edge-skyrmions pinned to the Pd/Fe island rim. Finally we have performed spin dynamics simulations to investigate the role of different magnetic parameters in causing these edge effects.

[1] I. Purnama *et al., Scientific Reports* **5**, 10620 (2015).
[2] N. Romming *et al. Science* **341**, 636-639 (2013).

MA 27.10 Thu 11:45 H37

Real-space determination of the isolated magnetic skyrmion deformation under electric current flow — Fehmi S. Yasin[1], •Jan Masell[1,2], Kosuke Karube[1], Akiko Kikkawa[1], Yasujiro Taguchi[1], Yoshinori Tokura[1,3], and Xiuzhen Yu[1] — [1]RIKEN CEMS, Wako, Japan — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [3]University of Tokyo, Tokyo, Japan

The effect of electric current on topological magnetic skyrmions, such as the current-induced deformation of isolated skyrmions, is of fundamental interest. The deformation has consequences ranging from perturbed dynamics to modified packing configurations. [1] We measure the current-driven real-space deformation of isolated, pinned skyrmions within CoZn at room temperature. We observe that the skyrmions are surprisingly soft, readily deforming during electric current application into an elliptical shape with a well-defined deformation axis. We find that this axis rotates towards the current direction, in agreement with our simply Thiele-based theoretical analysis. We quantify the average eccentricity and how the skyrmion size expands during current application. This first evaluation of in-situ electric current-induced skyrmion deformation paints a clearer picture of spin-polarized electron-skyrmion interactions and may prove essential when designing spintronic devices.

[1] J. Masell, D.R. Rodrigues, B.F. McKeever, and K. Everschor-Sitte, Phys. Rev. B 101, 214428 (2020). [2] Under review.

MA 27.11 Thu 12:00 H37

Magnetocrystalline anisotropy in cubic chiral magnets — •Vivek Kumar[1], Andreas Bauer[1], Schorsch Michael Sauther[1], Michelle Hollricher[1], Markus Garst[2], Marc Andreas Wilde[1], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany

Magnetocrystalline anisotropy plays an important role in the stabilization, orientation and manipulation of exotic spin textures like skyrmions in cubic chiral magnets [1-3]. Here, we report the determination of the fourth and sixth order anisotropy constants of MnSi as a function of temperature and field using the cantilever torque magnetometry option in a physical property measurement system. Torque curves were recorded by rotating the single-crystalline spherical sample in the field polarized state. This allows us to extract anisotropy constants by fitting the experimental data to the theoretical expressions of torques belonging to the symmetry class ($P2_13$). In addition, we discuss technical issues in measurement related to sample shape and geometry. The present technique is used to obtain the anisotropy constants of other cubic chiral magnets including Cu_2OSeO_3, $Mn_{1-x}Fe_xSi$ and $Fe_{1-x}Co_xSi$ series.

[1] Chacon *et al.*, Nat. Phys. **14**, 936 (2018).
[2] Bauer *et al.*, Phys. Rev. B **95**, 024429 (2017).
[3] Adams *et al.*, Phys. Rev. Lett. **121**, 187205 (2018).

MA 27.12 Thu 12:15 H37

Change of electronic Chern number induced by phase shifts in multiple-Q textures — •Pascal Prass[1], Fabian R. Lux[1], Duco van Straten[2], and Yuriy Mokrousov[1,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Institute of Mathematics, Johannes Gutenberg University Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany

A multiple-Q spin texture is given by the superposition of multiple spin spirals and gives rise to a periodic array of topological spin structures, such as skyrmions. Using the emergent magnetic field formalism [1] the topological Hall current in the texture is proportional to the real-space winding number of its spin vector field. In recent articles [2,3], it was illustrated how tuning the relative phase shifts of the spin waves as well as the textures' net magnetization leads to topological phase transitions in the spin texture, i.e. integer jumps of its winding number. Combining these ideas implies the existence of significant discontinuous jumps in the topological Hall current and its associated Chern numbers in the underlying electronic spectrum. In this work, we directly investigate the spin textures' electronic band topology to determine the relationship between its real-space winding number and quasi-momentum space Chern numbers. Understanding the electronic behaviour during these transitions will have far-reaching implications for developing tunable topological Hall devices. [1] T. Schulz et al. Nat. Phys. 8, 301-304 (2012). [2] K. Shimizu et al. arXiv:2201.03290 (2022). [3] S. Hayami et al. Nat. Commun. 12, 6927 (2021).

MA 27.13 Thu 12:30 H37

Audio Recognition with Skyrmion Mixture Reservoirs — •Robin Msiska[1], Jake Love[1], Jonathan Leliaert[2], Jeroen Mulkers[2], George Bourianoff[3], and Karin Everschor-Sitte[1] — [1]University of Duisburg-Essen, Duisburg, Germany — [2]Ghent University, Ghent, Belgium — [3]Senior Principle Engineer, Intel Corp. (Retired)

Physical reservoir computing is an information processing scheme that enables energy efficient temporal pattern recognition to be performed directly in physical matter [1]. Previously, random topological magnetic textures have been shown to have the characteristics necessary for efficient reservoir computing [2] and allowed for simple pattern recognition with two input channels [3].

We propose a skyrmion mixture reservoir computing model with multi-dimensional inputs. Through micro-magnetic simulations, we show that our implementation can solve audio classification tasks at the nanosecond timescale to a high degree of accuracy. Due to the quality of the results shown and the low power properties of magnetic texture reservoirs, we argue that skyrmion magnetic textures are a competitive substrate for reservoir computing.

Funding from the Emergent AI Centre (Carl-Zeiss-Stiftung), DFG (320163632), FWO-Vlaanderen and computer resources by VSC (Flemish Supercomputer Center) are gratefully acknowledged.

[1] G. Tanaka et al., Neural Networks 115, 100 (2019). [2] D. Prychynenko et al., Physical Review Applied 9, 014034 (2018) [3] D. Pinna et al., Phys. Rev. Applied 14, 054020 (2020)

MA 28: Magnonics 2

Time: Thursday 9:30–12:45 Location: H43

MA 28.1 Thu 9:30 H43

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

Non-linear processes are a key feature in the emerging field of spin-wave based information processing since they allow to convert uniform spin-wave excitations into propagating modes at different frequencies. Typically, non-linear spin-wave generation is well described by three and four-magnon scattering processes in the small modulation limit. Recently, the existence of non-linear magnons at odd half-integer multiples of the driving frequency (such as 3/2 f_{rf}, 5/2 f_{rf}, etc.) has been predicted for $Ni_{80}Fe_{20}$ at low bias fields [1]. However, it is an open question under which conditions these non-linear spin waves emerge coherently and how they can be manipulated in devices. Using super-Nyquist sampling MOKE [2] we directly image these non-linear spin waves in the strong modulation regime. The spatially-resolved investigation of such excitations in $Ni_{80}Fe_{20}$ elements reveals two distinct phase states [3]. Moreover, we use phase-locking to an external 'seed' frequency to activelymanipulate the phase state. These results open new possibilities for spin-wave sources and phase-encoded information processing with magnons.

[1] H. G. Bauer et al., NC 6:8274 (2015) [2] R. Dreyer et al., PRM 5(6):064411 (2021) [3] T. Makiuchi et al., APL 118, 022402 (2021)

MA 28.2 Thu 9:45 H43

Frequency multiplication by collective nanoscale spin wave dynamics — •Chris Körner[1], Rouven Dreyer[1], Martin Wagener[2], Niklas Liebing[1], Hans G. Bauer[3], and Georg Woltersdorf[1] — [1]Department of Physics, Martin Luther University HalleWittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Institute for Quantum Electronics, ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich, Switzerland — [3]Jahnstrasse 23, 96050 Bamberg, Germany

We observe all-magnetic frequency multiplication and the generation of a 6-octave spanning frequency comb within an extended polycrystalline NiFe layer [1]. We investigate this process by means of super Nyquist sampling MOKE microscopy [2] and diamond NV center spectroscopy. Our experimental observations in conjunction with micromagnetic simulations reveal the mechanism of this unexpected phenomenon.

At low bias fields the magnetization locally tilts due to a magnetic ripple effect in the NiFe film. Driving the magnetization with frequencies far below ferromagnetic resonance, i.e. in the MHz range, causes rapid synchronous switching. These switching processes lead to high harmonic spin wave emission. The spin waves emitted by multiple switching events across the film interfere and form a phase stable coherent spin wave frequency comb extending into the GHz regime.

[1] Koerner et al. Science, 375 (6585), 1165-1169 (2022) [2] Dreyer et al. Phys. Rev. Materials 5, 064411 (2021)

MA 28.3 Thu 10:00 H43

Hybridization Induced Spin-Wave Stop Band — •Christian Riedel, Takuya Taniguchi, and Christian H. Back — Technische Universität München

We present complex spin-wave diffraction patterns in the near-field diffraction limit by using a custom-made time-resolved magneto-optical Kerr effect (TR-MOKE) microscope for visualizing the local and time-resolved dynamic magnetization, i.e. propagating spin-waves. To investigate magnonic interference behaviors, we fabricate a diffraction grating in a 200 nm thick ferrimagnetic YIG film by argon ion-beam etching. A coplanar waveguide (CPW) located parallel to the grating, is used to coherently excite spin-waves. Our results represent the experimental realization of complex spin-wave interference patterns arising from various diffraction gratings, as preliminary investigated by Mansfeld et al.. We further demonstrate that the interference pattern behind the diffraction grating can be tuned through careful selection of the external magnetic field strength. A reduction in the effective magnetic field between the grating antidots can lead to a hybridization of two spin-wave modes and with this to a spin-wave transmission stop-band. This work contributes to the understanding of spin-wave interference behaviors for enhancing the performance of future magnonic devices.

MA 28.4 Thu 10:15 H43

Investigation of Spin Wave Caustics Phenomena — •Franz Vilsmeier[1], Alexis Wartelle[2], Takuya Taniguchi[1], and Christian Back[1] — [1]Technische Universität München — [2]Grenoble Institute of Technology

We present a systematic survey of caustic spin wave beams and their properties in an anisotropic magnetic environment.

Based on the theory from Kalinikos and Slavin for spin waves in soft films [Journal of Physics C: Solid State Physics, 1986, 19, 7013-7033], an anisotropic dispersion relation allows caustic points to exist. Here, several wavevectors with the same group velocity direction can be excited over a broad angular range within the sample plane. These caustic points result in nondiffractive spin wave beams and are characterised by their propagation direction, wavefront angle and wavelength.

Experimentally, we excite the caustic points in 200 nm thick Yttrium Iron Garnet by sending an rf current through a bow-shaped antenna. Time Resolved Kerr Microscopy is used to investigate the propagation behaviour both, spatially, as well as time resolved. We are able to access one caustic pocket and detect caustic-like beams over a range of different rf frequencies and external magnetic field values. Furthermore, the caustic-like beams are used to directly observe anisotropic reflection phenomena and steering of the beams with rotation of the externally applied field. The findings are compared to micromagnetic simulations with the help of Mumax3.

MA 28.5 Thu 10:30 H43

The Optimization of Yttrium Iron Garnet Spin-wave Lenses for Amplification of Spin Waves — •Stephanie Lake[1], Philipp Geyer[1], Rouven Dreyer[1], Niklas Liebing[1], Philip Trempler[1], Evangelos Papaioannou[1], Georg Woltersdorf[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, MartinLuther-Universität Halle-Wittenberg, 06120 Halle, Germany

Exciting magnons in magnetic materials for high-frequency applications is inefficient; one way to improve the process is to focus a manifold of spin waves. Following this idea, we create a magnon counterpart to the nonimaging Fresnel lens concentrator called a "spin-wave lens."

We simulate spin-wave (SW) propagation through funnel-like SW lenses based on the material Yttrium Iron Garnet (YIG) using Mumax [1]. When a frequency of 3.25 GHz and field of 51.62 mT are applied, SW modes with wavelengths 9.4 μm are excited, and furthermore, have a 384-fold increase in their intensity relative to the structure's start.

To test the simulation's accuracy, we fabricate SW lenses out of YIG [2] and measure the precession of excited SWs by a magneto-optic Kerr effect (MOKE) measurement scheme. We conduct several parameter sweeps of geometric characteristics and experimental conditions and currently attain a 51-fold increase in intensity near the funnel's exit for a frequency of 3.68 GHz and magnetic field of 66.15 mT.

[1] A. Vansteenkiste, et al., *AIP Adv.* **4**, 107133 (2014).
[2] F. Heyroth, et al., *Phys. Rev. Appl.* **12**, 054031 (2019).

MA 28.6 Thu 10:45 H43

Exchange spin waves excitation in nanoscale magnonic waveguides using deeply nonlinear phenomena — •Qi Wang[1,2], Roman Verba[3], Björn Heinz[4], Michael Schneider[4], Ondřej Wojewoda[5], Carsten Dubs[6], Norbert Norbert[2], Michal Urbánek[5], Philipp Pirro[4], and Andrii Chumak[1] — [1]Faculty of Physics, University of Vienna, Vienna, Austria — [2]Wolfgang Pauli Institute c/o Faculty of Mathmatics, University of Vienna, Vienna, Austria — [3]Institute of Magnetism, Kyiv, Ukraine — [4]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [5]CEITEC BUT, Brno University of Technology, Brno, Czech Republic — [6]INNOVENT e.V., Technologieentwicklung, Jena, Germany

High-speed and ultrashort waves with pronounced nonlinear phenomena are an ideal medium for wave-based computing. Spin waves, and their quanta magnons, meet all the requirements and are prospective data carriers in future signal processing systems. However, an efficient method for the excitation of short-wavelength spin waves is still an unsolved problem and a major obstacle for broadband spin-wave applications. Here, we present a universal approach to excite spin waves with wavelengths from micrometers down to tens of nanometers in nanoscale waveguides by exploiting deep nonlinear phenomena and validate it experimentally by microfocused Brillouin light scattering spectroscopy. The novel excitation method removes the wavelength limitations imposed by the antenna size, increases the excitation efficiency of short spin waves, and enables direct on-chip integration.

MA 28.7 Thu 11:00 H43

Symmetry of the magnetoelastic interaction of Rayleigh- and shear horizontal-magnetoacoustic waves — •Matthias Küss[1], Michael Heigl[1], Luis Flacke[2,3], Andreas Hefele[1], Andreas Hörner[1], Mathias Weiler[2,3,4], Manfred Albrecht[1], and Achim Wixforth[1] — [1]University of Augsburg, Experimental Physics I and IV — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften — [3]Physics-Department, Technical University Munich, 85748 Garching, Germany — [4]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern

Surface acoustic waves (SAWs) have made their way into many everyday devices. These "nano earthquakes" can be efficiently launched and detected on piezoelectric substrates with periodic metallic gratings. Resonant coupling of SAWs with spin waves (SWs) is the basis for an energy-efficient approach towards SW manipulation. In addition, magnetoacoustic interaction affects the properties of the SAW, which in turn can be used to devise new types of microwave devices. However, SAW-SW coupling is limited to certain experimental geometries, defined by the orientation of the static magnetization with respect to the SW wave vector. This orientation dependence is caused by the SAW mode-specific symmetry of the magnetoelastic driving fields. In this contribution, we demonstrate how the SAW mode-shape determines the symmetry of the magnetoelastic interaction and its nonreciprocal behavior, caused by the SAW-SW helicity mismatch effect [M. Küß et al., Phys. Rev. Applied 15, 034046 (2021)].

MA 28.8 Thu 11:15 H43

Direct maskless magnetic patterning using a cobalt focused ion beam — Javier Pablo-Navarro[1], •Kilian Lenz[1], Nico Klingner[1], Gregor Hlawacek[1], Ryszard Narkowicz[1], Lothar Bischoff[1], Rene Hübner[1], Wolfgang Pilz[2], Fabian Meyer[2], Paul Mazarov[2], and Jürgen Lindner[1] — [1]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Raith GmbH, Konrad-Adenauer-Allee 8, 44263 Dortmund

We present direct maskless magnetic patterning of ferromagnetic nanostructures using a novel liquid metal alloy ion source for focused ion beam systems (FIB). We used a $Co_{36}Nd_{64}$ alloy as the FIB source. A Wien mass filter allows for quick switching between the ion species in the alloy without changing the source. A single $5 \times 1 \times 0.05$ μm^3 permalloy strip served as the sample. Using the FIB we implanted a 300 nm wide track with Co ions. We observed the Co-induced changes by measuring the sample with microresonator ferromagnetic resonance before and after the implantation. Structures as small as 30 nm can be implanted up to a concentration of 10 % at the surface. Such lateral resolution is hard to reach for other lithographic methods. In contrast to electron beam lithography with broad beam ion implantation, the maskless FIB process does not require the complicated and difficult removal of the ion-hardened resist if optical measurements like BLS or MOKE are needed.

MA 28.9 Thu 11:30 H43

Experimental Detection of Magnon Noise Enhancement near Spin Reorientation in $Sm_{0.7}Er_{0.3}FeO_3$ — •Marvin Weiss[1], Andreas Herbst[1], Julius Schlegel[1], Martin Evers[1], Tobias Danegger[1], Andreas Donges[1], Makoto Nakajima[2], Sebastian T. B. Goennenwein[1], Alfred Leitenstorfer[1], Ulrich Nowak[1], and Takayuki Kurihara[1,3] — [1]Department of Physics, University of Konstanz — [2]ILE, Univ. Osaka — [3]ISSP, Univ. Tokyo

Disentangling intrinsic quantum mechanical interactions and thermal fluctuations is especially important for understanding and controlling magnetic phase transitions. In solids, the dynamics of thermal fluctuations of elementary excitations typically proceed on a picosecond timescale. Although optical pump-probe experiments give access to this range, the experimental detection of ultrafast spin fluctuations remains largely unexplored due to their incoherent character. We investigate the elementary dynamics of thermally excited incoherent magnons in the time domain with femtosecond resolution. The experiments are enabled by a novel setup that allows for extracting the correlation of the pulse-to-pulse polarization fluctuations between two temporally and spectrally separated femtosecond probe pulses that transmit through the sample. As a proof-of-principle demonstration, we study the critical phenomena around the spin reorientation transition (SRT) of the orthoferrite $Sm_{0.7}Er_{0.3}FeO_3$. Distinct changes of magnon noise amplitude and dynamics are mapped out around the SRT.

MA 28.10 Thu 11:45 H43

Lattice-driven femtosecond magnon dynamics in α-MnTe — •Kira Deltenre[1], Davide Bossini[2], Mirko Cinchetti[1], Götz S. Uhrig[1], and Frithjof B. Anders[1] — [1]Department of Physics, TU Dortmund University, D-44227 Dortmund — [2]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz

The femtosecond dynamics of the sublattice magnetizations in the antiferromagnetically ordered phase of α-MnTe is investigated theoretically with linear spin wave theory as a function of an external drive [1]. We assume that collective coherent lattice vibrations generated by laser pulses induce an oscillating Heisenberg coupling thus inducing the driving. The calculated dynamics of the antiferromagnetic order parameter exhibits damped coherent longitudinal oscillations, which decay due to dephasing. The frequency of the oscillations is determined by the external driving phonon. We make contact to experiments [2] by analyzing the spin dynamics for realistic parameters and discussing the effect of oscillating Heisenberg couplings between different types of (next-)nearest neighbors.

[1] K. Deltenre, D. Bossini, F. B. Anders, and G. S. Uhrig, Phys. Rev. B **104**, 184419 (2021)
[2] D. Bossini, S. D. Conte, M. Terschanski, G. Springholz, A. Bonanni, K. Deltenre, F. Anders, G. Uhrig, G. Cerullo, and M. Cinchetti, Phys. Rev. B **104**, 224424 (2021)

MA 28.11 Thu 12:00 H43

Hybrid magnon-quantum spin defects system in SiC — •Mauricio Bejarano[1,2], Francisco J. T. Goncalves[3], Toni Hache[4], Michael Hollenbach[1,2], Christopher Heins[1], Tobias Hula[1,5], Yonder Berencén[1], Georgy V. Astakhov[1], and Helmut Schultheiss[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]X-Fab, Dresden, Germany — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany — [5]Technische Universität Chemnitz, Chemnitz, Germany

Hybrid magnon-quantum spins systems have been gathering scientific interest in the last years due to their increased coupling strength, scalability down to the nanoscale regime and their potential as energy efficient quantum buses. While magnon-mediated control of quantum spins has been demonstrated with NV-centers in diamond, it has remained elusive on the silicon carbide (SiC) platform mainly due to the absence of a resonance overlap between the magnetic system and the spin-defect center. Here we circumvent this challenge by harnessing non-linear magnon scattering processes taking place in a magnetic vortex to access spin-wave eigenmodes that overlap with the intrinsic resonance of silicon vacancy defect centers in 4H-SiC. Our results offer a route to develop hybrid magnon-quantum spins systems that benefit from the electrical and optical properties of SiC for future quantum computing applications. This work was supported in part by the German Research Foundation under Grants SCHU 2922/4-1 and AS 310/9-1.

MA 28.12 Thu 12:15 H43

Topological magnons driven by the Dzyaloshinskii-Moriya interaction in the centrosymmetric ferromagnet Mn_5Ge_3 — •Manuel dos Santos Dias[1,2], Nikolaos Biniskos[3], Flaviano José dos Santos[4], Karin Schmalzl[5], Jörg Persson[6], Nicola Marzari[4], Stefan Blügel[2], Thomas Brückel[6], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, FZ Jülich & JARA, Jülich, DE — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, Duisburg, DE — [3]FZ Jülich, Jülich Centre for Neutron Science at MLZ, Garching, DE — [4]Theory and Simulation of Materials and National Centre for Computational Design and Discovery of Novel Materials, EPFL, Lausanne, CH — [5]FZ Jülich, Jülich Centre for Neutron Science at ILL, Grenoble, FR — [6]FZ Jülich, Jülich Centre for Neutron Science and Peter Grünberg Institut, JARA-FIT, Jülich, DE

The Berry phase of electrons and magnons can lead to various unique transport effects and protected edge states of topological nature. Here, we show theoretically and via inelastic neutron scattering experiments that bulk ferromagnetic Mn_5Ge_3 hosts topological Dirac magnons. Although inversion symmetry prohibits a net Dzyaloshinskii-Moriya interaction in the unit cell, it is locally allowed and is responsible for the gap opening in the magnon spectra. This gap is predicted and experimentally verified to close by rotating the magnetization from being parallel to being perpendicular to the *c*-axis. The tunability of Mn_5Ge_3 by chemical doping or by thin film nanostructuring makes it an exciting new platform to explore and design topological magnons.

MA 28.13 Thu 12:30 H43

Electric field control of magnons in magnetic thin films: Ab initio predictions for two-dimensional metallic heterostructures — •Alberto Marmodoro[1], Sergiy Mankovsky[2], Hubert Ebert[2], Jan Minár[3], and Ondřej Šipr[1,3] — [1]Institute of Physics (FZU) of the Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Chemistry, Ludwig-Maximilians-University (LMU), Munich, Germany — [3]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

We report on a possible venue to control magnons in 2D heterostructures by an external electric field acting across a dielectric barrier [1]. By performing ab initio 2D TB-KKR calculations for a Fe monolayer and Fe bilayer, both suspended in vacuum and deposited on Cu(001), we demonstrate that external electric field can significantly modify magnon lifetimes and that these changes can be related to field-induced changes in layer-resolved electronic Bloch spectral function. Further changes appear in cases with more than a single magnetic layer, and are strongly dependent on the presence of the substrate.

[1] Phys.Rev. B 105, 174411 (2022)

MA 29: Caloric Effects in Magnetic Materials

Time: Thursday 9:30–11:45 Location: H47

MA 29.1 Thu 9:30 H47

"Giant" magnetocaloric effects for 2nd order phase transition near 20 K: a study on rare-earth Laves phases for hydrogen liquefaction — •Wei Liu[1], Franziska Scheibel[1], Tino Gottschall[2], Eduard Bykov[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Funktionale Materialien, Technische Universität, TU Darmstadt, Germany — [2]Hochfeld- Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Hydrogen will play a key role for building a climate-neutral society, where renewables are the major energy sources [1]. Liquid hydrogen is essential for efficient storage and transport of hydrogen, but expensive due to the low efficiency of traditional gas-compression refrigeration [2]. As an emerging and energy-saving technology, magnetocaloric gas liquefaction can be an a "game-changer". Here we report a noticeable, but unaddressed feature for magnetocaloric hydrogen liquefaction using rare-earth-based intermetallic alloys: magnetocaloric effect of a 2nd order magnetocaloric materials can become "giant" when the Curie temperature TC is near the hydrogen boiling point of 20 K. Based on our study on rare-earth Laves phases for hydrogen liquefaction and a comprehensive literature review, we summarized two phenomenological rules for a rare-earth-based intermetallic series: (1) magnetic entropy change increases with decreasing TC; (2) adiabatic temperature change decreases firstly with decreasing TC but increases in cryogenic temperature range. These findings are well interpreted by a mean-field approach. Our studies can guide the materials design for hydrogen liquefaction.

MA 29.2 Thu 9:45 H47

Magnetocaloric effect in Tb_3Ni studied in high magnetic fields for cryogenic applications — •T. Niehoff[1,2], T. Gottschall[1], C. Salazar Mejia[1], A. Herrero[3], A. Oleaga[3], A.F. Gubkin[4], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Universidad del País Vasco, Bilbao, Spain — [4]Ekaterinburg, Russia

Tb_3Ni exhibits a large variety of temperature and magnetic-field dependent phase transitions in a temperature range of 3 to 90 K. This gives rise to a very competitive conventional magnetocaloric effect and an inverse magnetocaloric effect at very low temperature. These properties make this material an interesting candidate for magnetic refrigeration applications in the gas liquefaction temperature range. In this work, we present a comprehensive analysis of the magnetocaloric effect in a Tb_3Ni single crystal in pulsed magnetic fields up to 50 T and by heat capacity measurements in static fields.

MA 29.3 Thu 10:00 H47

Direct measurements of the adiabatic temperature change of holmium for cryogenic applications — •E. Bykov[1,2], T. Gottschall[1], Y. Skourski[1], C. Salazar Mejia[1], J. Wosnitza[1,2], M. D. Kuz'min[3], Y. Mudryk[4], D. L. Schlagel[4], and V. Pecharsky[4,5] — [1]1Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Aix-Marseille Université, IM2NP, Marseille, France — [4]Ames Laboratory, U.S. Department of Energy, Iowa State University, Ames,USA — [5]Department of Materials Science and Engineering, Iowa State University, Ames, USA

Rare-earth elements and their intermetallic compounds are interesting candidate materials for magnetic cooling at and below room temperature. Holmium demonstrates one of the largest magnetic moment in the lanthanide series and possesses other unusual magnetic properties. This metal exhibits numerous magnetic phase transitions as the temperature and/or magnetic field vary. Its Néel temperature accounts for $T_N = 132$ K, and its Curie temperature is $T_C = 20$ K resulting in a strong magnetocaloric effect in a large temperature window. This fact makes holmium a promising single-stage refrigerator material in an AMR (active magnetic regenerator) scheme for the liquefaction of natural gas and hydrogen. In this work, we present a comprehensive analysis of the magnetocaloric effect in a holmium single crystal in high magnetic fields up to 60 T.

MA 29.4 Thu 10:15 H47

Anomalous Nernst effect in ferromagnetic τ-MnAl thin films — •Daniel Scheffler[1], Helena Reichlova[1], Sebastian Beckert[1], Torsten Mix[2], Thomas G. Woodcock[2], Sebastian T. B. Goennenwein[3], and Andy Thomas[1,2] — [1]Technische Universität Dresden — [2]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden) — [3]University of Konstanz

τ-MnAl is a ferromagnetic compound with high uniaxial magnetocrystalline anisotropy. In single crystalline films, the anomalous Hall effect and the tunnel magnetoresistance effect have been investigated, the magneto-thermal transport properties of τ-MnAl films are unknown. Given the unique anisotropy, this material could allow for a robust spontaneous anomalous Nernst effect generated by a thermal gradient applied in the film plane.

We have sucessfully grown single crystalline τ-MnAl thin films via co-sputtering. X-ray diffraction and DC magnetometry confirm a good structural quality and strong perpendicular magnetic anisotropy. We observe a robust anomalous Hall effect with a coercivity of 1 T in magneto-transport measurements. In the same device, a defined thermal gradient can also be applied in the sample plane, resulting in a clear anomalous Nernst effect response.

We will present results from our magneto-transport and magneto-thermopower experiments, which in particular allow to quantify the anomalous Nernst effect coefficient. Our results show that τ-MnAl in thin film form is an interesting material for spin-caloritronic research and devices.

MA 29.5 Thu 10:30 H47

Magnonic to electronic spin current conversion in a quantum dot hybrid system with magnetic insulator — •Emil Siuda and Piotr Trocha — Faculty of Physics, Institute of Spintronics and Quantum Information, Adam Mickiewicz University, ul. Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland

One of the challenges of further miniaturization of electronic components is managing heat generated due to the Joule heating and other effects. While magnonics offers a way to reduce generation of the waste heat in the device it is still impossible to get rid of it entirely. Hence a way of converting heat to useful electric power is desirable.

We investigate a hybrid system which utilizes a temperature gradient to produce a magnon current and converts it to a spin electronic current. The considered system consists of a quantum dot coupled to the two ferromagnetic insulators or one ferromagnetic insulator and one ferromagnetic metal. This work focuses on the influence of energy-dependent density of states and many-body magnon interactions in the magnonic reservoirson the thermally induced spin transport through the system. Energy-dependent density of states is crucial for boson-like particles, especially in the low energy limit where the lowest momentum states dominate the tranport. Thus, in the present work we consider explicit energy dependence of the density of states for the magnonic reservoirs. Moreover, taking into account many-body magnon interactions leads to a temperature-dependent density of states of magnons which results in temperature-dependent couplings of the dot to the magnonic reservoirs.

MA 29.6 Thu 10:45 H47

Magneto-thermal transport in non-collinear antiferromagnetic thin films — •Sebastian Beckert[1], João Godinho[2,4], Freya Johnson[3], Jozef Kimák[4], Eva Schmoranzerová[4], Zbyněk Šobáň[2], Kamil Olejník[2], Jan Zemen[5], Joerg Wunderlich[6], Petr Němec[4], Dominik Kriegner[1,2], Lesley F. Cohen[3], Andy Thomas[1,7], Sebastian T. B. Goennenwein[8], and Helena Reichlová[1,2] — [1]TU Dresden — [2]IoP ASCR Prague — [3]Imperial College London — [4]Charles University — [5]Czech TU — [6]University of Regensburg — [7]IFW Dresden — [8]University of Konstanz

Understanding the interplay between topological properties and transport phenomena in non-collinear antiferromagnets is important for exploiting their unconventional characteristics in spintronics. Non-collinear antiferromagnets can exhibit phenomena previously known to be exclusive to ferromagnets, such as the anomalous Hall Effect (AHE) or the anomalous Nernst effect (ANE).

We experimentally study magneto-thermal transport in a Mn_3NiN thin film antiferromagnet. In our films the spins are arranged in the (111) plane, resulting in a component of the Hall vector in both out-of plane and in-plane direction. This makes Mn_3NiN an ideal candidate for a systematic study of magneto-thermal transport phenomena. We will present measurements of ANE, AHE, magnetoresistance and magneto-Seebeck effect measured in a single device. We will compare the amplitudes of the magneto-thermal transport coefficients and discuss them in context of the Mott relation.

MA 29.7 Thu 11:00 H47

Multicaloric all-d-metal Ni-Co-Mn-Ti Heusler alloys: Heat treatment optimization and arrested martensitic transformations — •Benedikt Beckmann[1], Andreas Taubel[1], Lukas Pfeuffer[1], David Koch[1], Tino Gottschall[2], Franziska Scheibel[1], Konstantin P. Skokov[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Institute of Material Science, 64287 Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Dresden 01328, Germany

Ni-Mn-based Heusler alloys display precisely tunable first-order martensitic transformations and are promising candidates for multicaloric cooling applications [1]. In our work, all-d-metal $Ni_{50-x}Co_xMn_{50-y}Ti_y$ Heusler alloys, showing an enhanced mechanical stability, are analyzed in detail [2]. A systematic heat treatment optimization results in a tailored microstructure and leads to large isothermal entropy changes up to 38 $J(kgK)^{-1}$ and adiabatic temperature changes up to -3.8 K for the first field application in moderate magnetic field changes of 2 T. The contradictory role of the magnetic entropy contribution [3], which leads to arrested martensitic transformations in $Ni_{50-x}Co_xMn_{50-y}Ti_y$ inverse magnetocaloric Heusler alloys, is discussed in detail.

We acknowledge financial support from DFG (CRC/TRR 270) and ERC (Adv. Grant No. 743116).

[1] T. Gottschall *et al.*, Nat. Mater. 17, 929-934 (2018)
[2] A. Taubel *et al.*, Acta Mater. 201, 425-434 (2021)
[3] T. Gottschall *et al.*, Phys. Rev. B 93, 184431 (2016)

MA 29.8 Thu 11:15 H47

Magnetocaloric effect of Gd - an realistic ab-initio study — •Rafael Vieira[1,2], Olle Eriksson[1,3], Torbjörn Björkman[2], and Heike C. Herper[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Physics, Faculty of Science and Engineering, Åbo Akademi University, FI-20500 Turku, Finland — [3]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden

We present a computational approach to evaluate field-dependent entropy of magnetocaloric materials from ab-initio calculations. Taking hcp Gd as a test system, we fully characterize the entropy associated with the magnetocaloric effect by including the entropy's electronic, lattice, and magnetic contributions.

The 2nd order nature of the ferromagnetic (FM)$\rightarrow$paramagnetic (PM) transition in Gd implies considering intermediate states of magnetic disorder. We describe the properties of these intermediate states as weighted averages of the properties of the FM and PM phases, with mixing weights defined by the magnetization of the system at a given temperature, to which we use the results from the Monte Carlo simulations. This approach allows a realistic system description, bringing the total entropy variation in agreement with reported measurements.

We find, as expected that the magnetic entropy is the dominant entropy. However, we also observe that the lattice contribution has a role in total entropy variation.

MA 29.9 Thu 11:30 H47

Eletrochemical corrosion study of La(FeSi)13H1,5 in diverse chemical environments — •Ulysse Rocabert[1], Falk Munch[2], Maximilian Fries[2], Benedict Beckmann[1], Konrad Loewe[3], Hugo Vieyra[3], Matthias Katter[3], Alexander Barcza[3], Wolfgang Ensinger[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt — [2]MagnoTherm Solutions GmbH — [3]Vacuumschmelze GmbH & Co

Hydrogenated La(FeMnSi)13 alloys represent a promising material class for magnetocaloric cooling at ambient temperatures, but contain highly oxophilic elements and are chemically sensitive. The development of protection strategies ensuring long-term stability is required and so analysis focused on Linear sweep voltammetry as the main analytical tool were performed in preferably buffered electrolytes with pH values reaching from moderately acidic to strongly alkaline to study different passivation strategies.

MA 30: Surface Magnetism

Time: Thursday 9:30–11:30 Location: H48

MA 30.1 Thu 9:30 H48

Interplay of magnetic states and hyperfine fields of iron dimers on MgO(001) — •SUFYAN SHEHADA[1,2,3], MANUEL DOS SANTOS DIAS[4,1], MUAYAD ABUSAA[3], and SAMIR LOUNIS[1,4] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Department of Physics, Arab American University, Jenin, Palestine — [4]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany

Individual nuclear spin states can have very long lifetimes and could be useful as qubits. Progress in this direction was achieved on MgO/Ag(001) via detection of the hyperfine interaction (HFI) of Fe, Ti and Cu adatoms using scanning tunneling microscopy (STM)[1,2]. Previously, we systematically quantified from first-principles the HFI for the whole series of 3d transition adatoms (Sc-Cu) deposited on various ultra-thin insulators, establishing the trends of the computed HFI with respect to the filling of the magnetic s- and d-orbitals of the adatoms and on the bonding with the substrate[3]. Here we take one step further by investigating the impact of the magnetic coupling between the dimer atoms on the HFI of Fe dimers on MgO(001) and its dependence on where the Fe atoms are located on the surface[4]. –Work funded by (BMBF–01DH16027).

[1] Willke *et al.*, Science **362**, 336 (2018); [2] Yang *et al.*, Nat. Nano. **13**, 1120 (2018); [3] Shehada *et al.*, Npj Comput. Mater. **7**, 87 (2021). [4] Shehada *et al.*, *arXiv.* **2202.00336** (2022).

MA 30.2 Thu 9:45 H48

Low-energy end states in proximitized antiferromagnetic nanowires — •LUCAS SCHNEIDER[1], PHILIP BECK[1], THORE POSSKE[2,3], LEVENTE RÓZSA[4], JENS WIEBE[1], and ROLAND WIESENDANGER[1] — [1]Department of Physics, Universität Hamburg, D-20355 Hamburg, Germany — [2]I. Institute for Theoretical Physics, Universität Hamburg, D-20355 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Magnetically ordered nanowires coupled to a superconducting surface have been proposed to host Majorana modes (MMs) at their ends, which form a single, highly non-local fermionic state together. While multiple experiments claim the observation of MMs via a zero-bias resonance in tunneling conductance at the ends of nanowires, this is not a unique signature of MMs. In this work, we study the emergence of low-energy end states in artificially crafted antiferromagnetic nanowires on two different superconducting surfaces using scanning tunneling spectroscopy. While some of the end states are observed close to zero energy, we find that they can be split into two non-degenerate components localized on the left and right ends by local defects - in clear contrast to expectations for a single non-local state. The phenomenology of these trivial bound states can be explained by simple toy-model calculations. We propose that similar perturbations by local defects could be used on other sample systems to probe the stability of candidate topological edge modes against local disorder.

MA 30.3 Thu 10:00 H48

Spin-resolved Fermi Surface of "Half-Metallic" FePd Alloy Monolayers — •XIN LIANG TAN[1,2], KENTA HAGIWARA[1,2], YING-JIUN CHEN[1,2], VITALIY FEYER[1], CLAUS M. SCHNEIDER[1,2], and CHRISTIAN TUSCHE[1,2] — [1]Forschungszentrum Jülich, Peter Grünberg Institut, Jülich — [2]Fakultät für Physik, Universität Duisburg-Essen, Duisburg

Magnetism in reduced dimensions is one of the preconditions for the realization of nanoscale spintronics. Despite the recent discovery of ferromagnetism in monolayers of two-dimensional materials, tunability and engineering on such systems are challenging. Here we present the electronic structure of ultrathin ferromagnetic iron-palladium alloy films using spin-resolved momentum microscopy. Momentum microscopy enables the two-dimensional detection of photoelectrons with an in-plane crystal momentum over the full Brillouin zone. By employing an imaging spin filter, spin-resolved momentum maps of the iron-palladium alloy were acquired. Breaking of time reversal symmetry by the remanent magnetization of the film manifests in a pronounced anisotropy of the electron states in the Fermi surface. In particular, the competition between exchange interaction and strong spin-orbit coupling in the FePd alloy leads to the formation of wave-vector dependent local gaps in the Fermi surface. Moreover, the spin-resolved maps recorded by the momentum microscope give evidence for a non-collinear spin texture of the electron states at the Fermi surface, where the local spin polarization vector points orthogonal to the remanent magnetization of the sample.

MA 30.4 Thu 10:15 H48

Real-time MOKE measurements of CoTMPP on magnetic Ni/Cu(110)-(2x1)O — •GIZEM MENDIREK[1], ALEKSANDER BROZYNIAK[2], MICHAEL HOHAGE[1], ANDREA NAVARRO-QUEZADA[1], and PETER ZEPPENFELD[1] — [1]Institute of Experimental Physics, Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz, Austria — [2]Christian Doppler Laboratory for Nanoscale Phase Transformations, Johannes Kepler University Linz, Altenberger Str. 69, 4040 Linz, Austria

In this work, we report the detailed analysis employing a fitting algorithm on a setup consisting of a combination of a sinusoidal modulation of the magnetic field with the synchronous detection of the reflectance difference spectroscopic MOKE (RD-MOKE) signal. This setup allows recording hysteresis loops continuously revealing relevant magnetic properties like magnetization amplitude, remanent magnetic signal and coercive field as a function of coverage, time or temperature with high precision in real-time. The capabilities of our setup and our analysis algorithm is demonstrated for Ni thin films grown on a Cu(110)-(2×1)O reconstructed surface with a sharp spin reorientation transition at 9 ML. Subsequently, the deposition of cobalt tetramethoxyphenylporphyrin (CoTMPP) thin films on the Ni/Cu(110)-(2×1)O system is investigated. The adsorption of the molecules induces characteristic changes in the magnetic properties such as the decrease of the Curie temperature of the Ni thin films upon CoTMPP deposition with different thicknesses.

MA 30.5 Thu 10:30 H48

Thermally-induced magnetic order from glassiness in elemental neodymium — BENJAMIN VERLHAC[1], •LORENA NIGGLI[1], ANDERS BERGMANN[2], UMUT KAMBER[1], ANDREY BAGROV[1,2], DIANA IUŞAN[2], LARS NORDSTRÖM[2], MIKHAIL I. KATSNELSON[1], DANIEL WEGNER[1], OLLE ERIKSSON[2,3], and ALEXANDER A. KHAJETOORIANS[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [3]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden

While traditional spin glasses are characterized by randomness and frustration, elemental neodymium shows glassy behavior as a result of competing interactions, particularily without extrinsic disorder [1]. Adding to the list of intriguing effects found in spin glasses, e.g. aging and memory, we observe an unconventional magnetic phase transition from a glassy to a long-range ordered phase in Nd as temperature is increased [2]. To characterize the spatially varying magnetization patterns, we employ temperature-dependent spin-polarized scanning tunnelling microscopy between 5-15K along with atomistic spin dynamics simulations that support our findings. A new analysis method allows us to extract the phase transition temperature directly by evaluating our experimental data. Notably, such an unusual magnetic phase transition serves as a counterexample to the common thermodynamic understanding of temperature and disorder being synonymous.

[1] U. Kamber et al., *Science* **368** (2020).
[2] B. Verlhac et al., arXiv:2109.04815, accepted at Nat. Phys.

MA 30.6 Thu 10:45 H48

Distorted 3Q state driven by topological-chiral magnetic interaction — •Soumyajyoti Haldar[1], Sebastian Meyer[2], André Kubetzka[3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstr. 15, 24098 Kiel, Germany — [2]Nanomat/Q-mat/CESAM, Université de Liège, B-4000 Sart Tilman, Belgium — [3]Department of Physics, University of Hamburg, 20355 Hamburg, Germany

Non-collinear spin structures are of fundamental interest in magnetism since they allow to obtain insight into the underlying microscopic interactions and are promising for spintronic applications [1,2]. Here, we demonstrate that recently proposed topological-chiral magnetic interactions [3] can play a key role for magnetic ground states in ultrathin films at surfaces [4]. Using density functional theory we show that significant chiral-chiral interactions occur in hexagonal Mn monolayers due to large topological orbital moments which interact with the emergent magnetic field. Superposition states of spin spirals such as the 2Q state or a distorted 3Q state arise due to the competition with biquadratic and four-spin interactions. Simulations of spin-polarized scanning tunneling microscopy images suggest that the distorted 3Q state could be the magnetic ground state of a Mn monolayer on Re(0001).

[1] A. Fert *et al.*, Nat. Rev. Mater. **2**, 17031 (2017). [2] J. Grollier *et al.*, Nat. Electron. **3**, 360 (2020). [3] S. Grytsiuk *et al.*, Nat. Commun. **11**, 511 (2020). [4] S. Haldar *et al.*, Phys. Rev. B **104** L180404 (2021).

MA 30.7 Thu 11:00 H48

The mutual impact of magnetism on proximity-induced superconductivity — •Uriel Aceves[1,2], Filipe Guimaraes[3], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Faculty of Physics & CENIDE, University of Duisburg-Essen, 47053 Duisburg, Germany — [3]Jülich Supercomputing Centre, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

In a conventional superconductor (SC), vibrations on the crystal lattice can cause electrons to attract mutually and bind in the so-called Cooper pairs. At the interface of a normal metal (NM), Cooper pairs can wander from SC to NM resulting in a proximity induced gap. Electrons from NM can also travel into SC by normal transport or Andreev reflection. This exchange of electrons can impact the properties of both materials. Moreover, if the NM is magnetic new and exciting physics appears. In this work, we explore NM/SC interface phenomena by introducing a method to extract the tensor of magnetic exchange interactions within the framework of the Bogoliubov-de Gennes equations where superconductivity is induced via an effective electron-phonon coupling constant λ and accounting for spin-orbit coupling. Based on a realistic description of the electronic structure, we analyze the behaviour of the isotropic exchange and the Dzyaloshinskii-Moriya interaction as a function of λ on a Mn monolayer on top of a superconducting Nb (110) slab. Additionally, we investigate the impact of λ on the proximity-induced gap as a function of the direction of the magnetic moment in Mn.

MA 30.8 Thu 11:15 H48

Observation of spin-correlated exciton-polaritons in a van der Waals magnet — •Florian Dirnberger[1], Rezlind Bushati[1,2], Biswajit Datta[1], Ajesh Kumar[3], Allan H. MacDonald[3], Edoardo Baldini[3], and Vinod M. Menon[1,2] — [1]Department of Physics, City College of New York, New York, NY 10031, USA — [2]Department of Physics, The Graduate Center, City University of New York, New York, NY 10016, USA — [3]Department of Physics, University of Texas at Austin, Austin, TX 78712, USA

The recent discovery of optically active excitons in magnetic van der Waals crystals offers extraordinary opportunities to study collective phenomena in quantum materials via light-matter interactions. A prime candidate in this endeavor is nickel phosphorus trisulfide ($NiPS_3$), a van der Waals antiferromagnet with highly correlated magnetic and electronic degrees of freedom. By coupling optical fields to its excitonic excitations, we demonstrate a previously unobserved class of polaritons with unique signatures of excitons, photons and spins. A detailed spectroscopic analysis of these newly formed quasiparticles in conjunction with our microscopic theory shows that magnetically coupled excitations can have an origin and interactions that are distinct from those of excitons in conventional band semiconductors.

MA 31: Topological Insulators (joint session MA/KFM)

Time: Thursday 15:00–17:45 Location: H37

Invited Talk MA 31.1 Thu 15:00 H37

Neutron scattering on magnetic topological materials: From topological magnon insulators to emergent many-body effects — •Yixi Su — Jülich Centre for Neutron Science JCNS at MLZ, Forschungszentrum Jülich, 85747 Garching, Germany

Recent theoretical predictions and experimental realizations of exotic fermions and topologically protected phases in condensed matter have led to tremendous research interests in topological quantum materials. Especially, magnetic topological materials, such as magnetic Dirac and Weyl semimetals, and intrinsic magnetic topological insulators etc., in which non-trivial topology of single-electron band structures and electronic correlation effects are often intertwined, have emerged as an exciting platform to explore novel phenomena. Here I will present our recent neutron scattering studies. In the Dirac semimetal EuMnBi2, the evidence for the possible impact of magnetism on Dirac fermions is obtained via a detailed neutron diffraction study of the spin-flop transition [1]. Based on our inelastic neutron scattering study and theoretical analysis of spin-wave excitations, the exotic topological magnon insulators, the bosonic analogs of topological insulators, have been experimentally realized in the two-dimensional van der Waals honeycomb ferromagnets CrSiTe3 and CrGeTe3 [2]. Furthermore, in the magnetic Weyl semimetal Mn3Sn, an unusual magnetic phase transition that is driven by emergent many-body effects is revealed via a combined neutron scattering study and band-structure calculations [3].

[1] F. Zhu, et al., Phys. Rev. Research 2, 043100 (2020). [2] F. Zhu, et al., Sci. Adv. 7, eabi7532 (2021). [3] X. Wang (unpublished)

MA 31.2 Thu 15:30 H37

Tuning the magnetic gap of a topological insulator — •Marcus Liebmann[1], Philipp Küppers[1], Jannik Zenner[1], Stefan Wimmer[2], Gunther Springholz[2], Oliver Rader[3], and Markus Morgenstern[1] — [1]II. Phys. Inst. B, RWTH Aachen Univ., Germany — [2]Inst. Halbleiter- u. Festkörperphysik, Johannes Kepler Univ., Linz, Austria — [3]Helmholtz-Zentrum Berlin f. Mater. u. Energie, Germany

Mn-rich $MnSb_2Te_4$ is a ferromagnetic topological insulator with yet the highest Curie temperature $T_C = 45 - 50\,K$. It exhibits a magnetic gap at the Dirac point of the topological surface state that disappears above T_C. We probe the gap size by scanning tunneling spectroscopy, varying in-plane magnetic field $B_{||}$ and temperature. We demonstrate shrinkage of the average gap size with $B_{||}$ revealing that the gap opening originates from out-of-plane magnetization. In line, the gap does not close completely up to $B_{||} = 3\,T$ as the magnetization is only partially rotated in-plane. In addition, we demonstrate significant spatiotemporal fluctuations of the gap size at temperatures as low as $T_C/2$, above which the remanent magnetization indeed decays. Thus, the gap is tightly bound to the out-of-plane magnetization, as expected theoretically but not demonstrated experimentally yet. The partial in-plane rotation at $B_{||} = 3\,T$ and the low temperature onset of fluctuations stress the important role of competing magnetic orders in the formation of the favorable ferromagnetic topological insulator in Mn-rich $MnSb_2Te_4$, providing insight into the complex magnetic gap opening that is decisive for quantum anomalous Hall devices.

MA 31.3 Thu 15:45 H37

Local magnetic and electronic properties of the intrinsic magnetic topological insulator $MnBi_6Te_{10}$ — •Abdul-Vakhab Tcakaev[1], Volodymyr Zabolotnyy[1], Bastian Rubrecht[2], Laura Corredor[2], Jorge Facio[2], Laura Folkers[3], Anja Wolter[2], Anna Isaeva[2], and Vladimir Hinkov[1] — [1]Experimentelle Physik IV and R ontgen Research Center for Complex Materials (RCCM), Fakult at f ur Physik und Astronomie, Universit at W urzburg, Am Hubland, D-97074 W urzburg, Germany — [2]Leibniz IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany — [3]Faculty of Physics, Technische Universit at Dresden, D-01062 Dresden, Germany

The recent observation of novel phenomena in the intrinsic magnetic topological insulator $MnBi_2Te_4$, such as the quantum anomalous Hall effect and the topological magnetoelectric effect has prompted research of the higher-n members of the $(MnBi_2Te_4)(Bi_2Te_3)_n$ family. Here we combine x-ray absorption spectroscopy, and x-ray circular and linear dichroism at the Mn $L_{2,3}$ edges, with density-functional (DFT) and multiplet ligand-field (MLFT) theory to investigate the ground state of Mn in $MnBi_6Te_{10}$ single crystals. Our magnetometry data reveal FM state with finite remanence consistent with the spectroscopy data. Our spectroscopy results together with DFT and *ab initio* MLFT calculations allow us to determine in full detail the local magnetic and electronic properties of the Mn ions in the bulk and near the surface, and deliver important microscopic physical parameters, including Mn 3*d*-shell occupation, the spin and orbital magnetic moments.

MA 31.4 Thu 16:00 H37

Probing the Superconductor / Quantum Anomalous Hall Interface — •Anjana Uday[1], Gertjan Lippertz[1,2], Andrea Bliesener[1], Alexey Taskin[1], and Yoichi Ando[1] — [1]University of Cologne, Cologne, Germany — [2]KU Leuven, Leuven, Belgium

Recently, crossed Andreev conversion was reported in a hybrid quantum Hall (QH) / Superconductor (SC) system [1]. The evidence was based on the observation of a negative downstream resistance R_D in a three-terminal measurement of a Hall-bar device with respect to the grounded SC electrode. Similar experiments would be of great interest in the quantum anomalous Hall (QAH) / SC hybrid system, where superconductivity can be suppressed for control experiments by applying a magnetic field while keeping the 1D edge state unchanged. We fabricated Hall-bar devices from V-doped $(Bi_xSb_{1-x})_2Te_3$ thin films contacted with Nb electrodes having various widths. We found a finite positive R_D which increases with decreasing the widths of the SC electrode due to the QAH breakdown mechanism [2]. We also found a clear increase in R_D upon killing the superconductivity with a magnetic field for Nb electrodes narrower than 200 nm; this can be attributed to either non-local Andreev reflections on top of the breakdown-induced finite R_D or local Andreev reflections on the 2D normal metal/SC interface, which can be created by the charge transfer from the Nb electrode to the gapped VBST surface state. In both cases our observation implies a high transparency of the SC/QAH interface.

[1] G.-H. Lee et al., Nat. Phys. 13, 693-698 (2017)
[2] G. Lippertz et al., arXiv:2108.02081 (2021)

MA 31.5 Thu 16:15 H37

Magnetotransport Properties of MnSb2Te4 — •Michael Wissmann[1,2,3], Joseph Dufouleur[2], Anna Isaeva[4], Bernd Büchner[2,3], and Romain Giraud[1,2] — [1]Université Grenoble-Alpes, CNRS, CEA, SPINTEC, F-38000 Grenoble, France — [2]Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany — [3]Institute of Solid State Physics, TU Dresden, 01069 Dresden, Germany — [4]Department of Physics and Astronomy, University of Amsterdam,1098 XH Amsterdam, Netherlands

The new family of intrinsically magnetic van-der-Waals layered topological insulators Mn(Bi,Sb)Te, with strong spin-orbit coupling, is of great interest to investigate the interplay between topology and magnetic order in electronic band structures. When introducing magnetism into a 3D topological insulator, this interplay can generate topological quantum states like the quantum anomalous Hall effect (QAH) or the axion insulator, which can be modified by tuning the magnetization.

Our recent studies consider the MnSb2Te4 compound, a ferromagnet with a perpendicular-to-plane anisotropy and a critical Curie-Weiss temperature as high as 50K. MnSb2Te4 has been controversially discussed to be a magnetic Weyl semimetal or a candidate to realize the axion insulator. We investigated the thickness-dependent properties of exfoliated nanoflakes using magneto-transport, revealing the change in important parameters such as the resistivity, the Curie temperature and the magnetic coercive field. The influence of both the intrinsic electrical doping and disorder in magnetic topological insulators is considered as well.

MA 31.6 Thu 16:30 H37

Investigation of the magnetic and electronic properties of topological insulator/ferromagnet heterostructures — •Simon Marotzke[1,2], André Philippi-Kobs[1,2], Leonard Müller[1,3], Matthias Kalläne[2], Jens Buck[2], Wojciech Roseker[1], Nils Wind[3], Sanjoy Mahatha[4], Nils Huse[3], Gerhard Grübel[1,3], Martin Beye[1], and Kai Rossnagel[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Christian-Albrechts-Universität zu Kiel, Germany — [3]Universität Hamburg, Germany — [4]Thapar Institute of Engineering and Technology, Patiala, India

Heterostructures of the design Bi_2Se_3/X/Co/Pt, with X = None, Pt, B_4C or B_4C/Pt as separation layer between the topological insulator (TI) and the ferromagnetic overlayer are studied. By means of magneto-optical Kerr effect, the magnetic behaviour is characterised, showing that perpendicular magnetic anisotropy can be achieved in the overlayer and minutely tuned by changing layer properties. In X-ray photoemission spectroscopy measurements, two Bi phases are identified in the heterostructures. By systematically varying the photon energy, the depth, in which the two Bi phases are located, is analysed. Significant differences of the chemical properties at the interface to the TI are found for heterostructures consisting of Bi_2Se_3 with a metallic or insulating overlayer, respectively. Finally, a scheme to invert the heterostructures is presented, potentially enabling angle-resolved photoemission spectroscopy measurements on the TI's surface in future in order to study the influence of the magnetisation state on the TI's surface states.

MA 31.7 Thu 16:45 H37

Current-induced breakdown of the quantum anomalous Hall effect — •Gertjan Lippertz[1,2], Andrea Bliesener[1], Anjana Uday[1], Lino M.C. Pereira[2], Alexey Taskin[1], and Yoichi Ando[1] — [1]University of Cologne, Cologne, Germany — [2]KU Leuven, Leuven, Belgium

The quantum anomalous Hall (QAH) effect is characterised by zero longitudinal resistivity and quantized Hall resistance without the need of an external magnetic field. However, when reducing the device dimensions or increasing the current density, an abrupt breakdown of the dissipationless state occurs. In this talk, the mechanism of breakdown will be adressed, and the electric field created between opposing chiral edge states will be shown to lie at its origin. Electric-field-driven percolation of two-dimensional charge puddles in the gapped surface states of compensated topological-insulator films is proposed as the most likely cause of the breakdown [1].

Moreover, it was recently reported that the interplay between the 1D chiral edge state and the 2D surface state can give rise to nonreciprocity in the longitudinal resistance [2]. In this talk, it will be shown that the onset of 2D conduction due to breakdown is sufficient to create the nonreciprocal effect, allowing for efficient switching between the dissipationless and nonreciprocal transport regime of the QAH state.

[1] G. Lippertz et al., arXiv:2108.02081 (2021)
[2] K. Yasuda et al., Nat. Nanotechnol. 15, 831-835 (2020)

MA 31.8 Thu 17:00 H37

Thermal Hall Effect of Magnons in Collinear Antiferromagnets: Signatures of Magnetic and Topological Phase Transitions — •Robin R. Neumann[1], Alexander Mook[2], Jürgen Henk[1], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Department of Physics, University of Basel, Basel, Switzerland

While chiral edge states of topological bosons lack clear hallmarks and are difficult to detect, topological electrons can directly be identified by means of the quantized transverse conductivity intrinsic to the quantum anomalous Hall effect. In this talk I consider magnons, the bosonic quanta of collective spin excitations, in a collinear antiferromagnet that is driven from its antiferromagnetic phase via a spin-flop phase to the field-polarized phase by an external magnetic field. Besides the magnetic phase transitions, topological phases occur in the spin-flop and field-polarized phases. To identify these phase transitions, the thermal Hall effect (THE), i. e. the transversal heat transport induced by a longitudinal temperature gradient, is studied across the phase transitions. It is demonstrated that the THE exhibits pronounced signatures of the phase transitions and the temperature tunes the sensitivity to these phase transitions oppositely, allowing for their distinction in transport experiments.

MA 31.9 Thu 17:15 H37

Topology, Colossal Magnetoresistance, and Complex Magnetic Domains in Eu5In2Sb6 — •Marein Rahn[1,2], Murray N. Wilson[3], Priscila F. S. Thomas[2], Tom Lancaster[3], Filip Ronning[2], and Marc Janoschek[4,5] — [1]IFMP, TU Dresden, 01062 Dresden, Germany — [2]LANL, Los Alamos, New Mexico 87545, USA

— [3]Department of Physics, Durham University, Durham, DH1 3LE, UK — [4]Laboratory for Neutron and Muon Instrumentation, Paul Scherrer Institute, CH-5232 Villigen, Switzerland — [5]Physik-Institut, U. Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

The axion insulating state is a paradigm of topological correlated matter which has been particularly difficult to demonstrate in real materials. Using neutron scattering, resonant elastic x-ray scattering, muon spin-rotation and bulk measurements, we demonstrate how the combination of co-planar glide symmetries and large Eu2+ magnetic moments in the Zintl phase Eu5In2Sb6 produces an unusual two-step ordering process. At 14 K, Eu5In2Sb6 first forms a complex non-collinear weak Ising-ferrimagnet, which we identify as a trivial insulator. Below 7.5 K, this phase is continuously displaced by a growing volume fraction of a compensated antiferromagnetic arrangement that may have axion insulating character. This discovery also implies the presence of a solitonic antiferromagnetic domain structure on the mesoscale, which demonstrably couples to charge transport and, due to the net magnetization of some domains, should be highly susceptible to manipulation. This may open up a platform to engineer interfaces of trivial and non-trivial insulators on the mesoscale.

MA 31.10 Thu 17:30 H37

Invisible flat bands on a topological chiral edge — •Youjiang Xu, Irakli Titvinidze, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

We prove that invisible bands associated with zeros of the single-particle Green's function exist ubiquitously at topological interfaces of 2D Chern insulators, dual to the chiral edge/domain-wall modes. We verify this statement in a repulsive Hubbard model with a topological flat band, using real-space dynamical mean-field theory to study the domain walls of its ferromagnetic ground state. Moreover, our numerical results show that the chiral modes are split into branches due to the interaction, and that the branches are connected by invisible flat bands. Our work provides deeper insight into interacting topological systems.

MA 32: Bulk Materials: Soft and Hard Permanent Magnets

Time: Thursday 15:00–17:00 Location: H43

MA 32.1 Thu 15:00 H43

High-Entropy/Compositionally-Complex B2 Heusler alloy — •Asli Cakir[1,2], Mehmet Acet[2], and Michael Farle[2] — [1]Department of Metallurgical and Materials Engineering, Mugla University, 48000, Mugla,Turkey — [2]Fakultät für Physik, Universität Duisburg-Essen, Forsthausweg 2, 47057 Duisburg, Germany

High entropy alloys (HEAs) emerge as a new alloy concept contrary to conventional alloy design that includes one or two main elements with additional amounts of property-tuning elements. It has been established that the general physical properties of 3d-metallic HEAs can be understood within the known valence-electron-concentration scheme. Using this scheme alloys with particular physical properties can be designed. Here, we present a compositionally-complex alloy consisting of a HEA-component, MnFeCoNiCu, with 25 at% added Al. The resulting material is identical to a stoichiometric B2-Heusler alloy (HEA)50(HEA)25Al25. We have performed X-ray diffraction, energy-dispersive x-ray spectroscopy studies, and magnetization measurements. The alloy exhibits the ordered B2 structure with saturation-magnetization of 1.3 Bohr magneton and Curie temperature of 550 K.

MA 32.2 Thu 15:15 H43

Magnetic-field-, temperature- and time-dependence of structural and magnetic properties of shell-ferromagnets — •Nicolas Josten[1], Steffen Franzka[2], Mehmet Acet[1], Franziska Scheibel[3], Asli Çakir[4], Franziska Staab[5], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg Essen, Duisburg, 47057, Germany — [2]Interdisciplinary Center for Analytics on the Nanoscale (ICAN), Carl-Benz-Straße 199, 47057 Duisburg, Germany — [3]Functional Materials, Institute of Materials Science, Technical University of Darmstadt, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany — [4]Department of Metallurgical and Materials Engineering, Mugla University, 48000 Mugla, Turkey — [5]Physical Metallurgy, Institute of Materials Science, Technical University of Darmstadt, Alarich-Weiss-Str. 2, 64287 Darmstadt, Germany

The strong pinning of magnetic moments in off-stoichometric $Ni_{50}Mn_{45}X_{05}$ (X= Al, Ga, In, Sn, Sb) Heusler alloys after magnetic annealing at 650K is known as the shell-ferromagnetic effect. This pinning leads to coercive fields larger than 6 Tesla and is interesting for the development of novel ultrahard permanent magnets. We report on the optimization of the strength of this effect by varying the annealing field, time, and temperature. The origin of the effect is discussed based on these results combined with magnetic force microscopy images.

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

MA 32.3 Thu 15:30 H43

Effects of disorder on the magnetic properties of $L1_0$-FeNi — Ankit Izardar and •Claude Ederer — ETH Zürich, Switzerland

$L1_0$-ordered FeNi is a promising candidate for cheap mid-range permanent magnets. However, since the synthesis of fully ordered samples is very challenging, it is important to understand how deviations from perfect chemical order affect the magnetic properties of FeNi, in particular the magneto-crystalline anisotropy and Curie temperature. We use DFT in combination with a sampling over different supercell configuration to address effects of chemical disorder in FeNi. Our results show that a decrease in chemical order of up to 25 % does not cause a significant reduction of the magneto-crystalline anisotropy, and that the anisotropy can even be increased for Fe-rich compositions. We also show that the dominant magnetic coupling is strongly dependent on the specific chemical environment and vary drastically in the partially disordered system. We discuss these results in relation to alternative approaches to disorder, such as, e.g., the coherent potential approximation.

MA 32.4 Thu 15:45 H43

Influence of filler morphology, arrangement and filling fraction on the magnetic properties of polymer-bonded magnets produced by laser powder bed fusion — •Kilian Schäfer[1], Tobias Braun[1], Stefan Riegg[1], Jens Musekamp[2], and Oliver Gutfleisch[1] — [1]1Functional Materials, Institute of Materials Science, , Technical University Darmstadt, Darmstadt — [2]2Institute for Materials Technology (MPA-IfW), Technical University Darmstadt, Grafenstraße 2, D-64283 Darmstadt

Bonded permanent magnets are key components in many energy conversion, sensor and actuator devices. These applications need high magnetic performance, customizability, and freedom of shape. With additive manufacturing processes, for example laser powder bed fusion (LPBF), it is possible to produce bonded magnets with tailored stray field distribution.

Up to now, most studies use spherical powders as magnetic fillers due to their good flowability. Here, the behavior of large SmFeN platelets with a high aspect ratio as filler material and its influence on the arrangement and the resulting magnetic properties were examined. To study the distribution and orientation of the magnetic filler in 3D, computed tomography measurements were conducted and analyzed with the open-source software ImageJ. It is shown that the plateletshaped particles align themselves perpendicular towards the buildup direction during the process. In addition, the effect of filling fraction on the magnetic properties of the composites is investigated.

MA 32.5 Thu 16:00 H43

magnetocrystalline anisotropy in easy-plane kagomé ferromagnet Fe_3Sn — •Lilian Prodan[1], Vladimir Tsurkan[1,2], and István Kézsmárki[1] — [1]Experimental Physics V, Institute of Physics, University of Augsburg, D-86159 Augsburg, Germany — [2]Institute of Applied Physics, MD 2028, Chisinau, Republic of Moldova

Kagomé magnets are expected to host exotic magnetic and electronic properties due to possible interplay of spin-orbit coupling (SOC) and specific topology of the energy band structures [1,2,3]. Here, we present the field-dependent and angular-dependent magnetization studies of the kagomé -lattice easy-plane ferromagnet Fe_3Sn. The SOC is probed by the measurements of the magnetocrystalline anisotropy in high-quality bulk single crystals. Measurements in high fields reveal the difference in the saturation magnetization along the a and the c axes, which does not vanish up to the highest applied field of 14 T. The anisotropy evidenced in the saturation moment indicates a possible contribution of the orbital moment. The temperature dependence of the magnetocrystalline anisotropy constants K_1 and K_2 was determined. [1] L. Ye et al., Nature 555, 638 (2018), M. Altthaler et al., Phys. Rev. Research 3, 043191 (2021), J. Watanabe, et al., arXiv:2202.06665 (2022).

MA 32.6 Thu 16:15 H43

First principles study of the complex magnetism in Ce_2Fe_{17} — Alena Vishina[1], Olle Eriksson[1,2], Anders Bergman[1], and •Heike C. Herper[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]School of Science and Technology, Örebro University, Örebro, Sweden

With its comparably low cost and high magnetization the intermetallic Ce_2Fe_{17} has potential to become a candidate for permanent magnets. Problems arising from the in-plane magnetocrystalline anisotropy and the low T_C could be overcome by doping with light elements. Despite that, there is an ongoing debate regarding the magnetic phases in Ce_2Fe_{17}. While a large number of partially seemingly contradicting experimental findings have been reported, only few theoretical studies exist and they do not capture the experimental findings. Performing a comprehensive study of the magnetic properties of Ce_2Fe_{17} we applied various approaches for the exchange-correlation functional to identify the best theoretical treatment of the system. To account for the mixed valent nature of Ce_2Fe_{17} we tested several approximations including an analysis of the hybridization function. We used a combination of ab initio methods (VASP, FP-LMTO RSPt) to obtain geometrical and magnetic data including magnetic exchange parameters.

Our results [1] clearly show that the ground state is non-collinear with a strong FM component which explains the low magnetic moment reported in experiment. At 93 K the FM component vanishes and we observe correctly the transition to the helical state.

[1] A. Vishina et al., JALCOM **888**, 161521 (2021)

MA 32.7 Thu 16:30 H43

High-throughput and data-mining search for novel rare-earth-free permanent magnets — •Alena Vishina[1], Heike Herper[1], and Olle Eriksson[1,2] — [1]Department of Physics and Astronomy, Uppsala University, Se-75120 Uppsala, Sweden — [2]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden

Rare-earth (RE) magnetic materials dominate the market when high-performance permanent magnets are needed (e.g. the area of 'green' energy technology, such as electric vehicles and windmills). At the same time, there is a growing interest in RE-free alternatives, since the heavier RE elements are quite expensive and are often mined with methods that leave an environmental footprint. We propose to use the data-mining approach to search for high-performance RE-free/lean magnetic materials. Filtering through a large number of known structures from ICSD database, we are looking for materials with high magnetization M > 1 T, uniaxial MAE > 1 MJ/m3, and Tc >300 K. Sometimes, additional elements alterations are attempted to make the material more cost-effective. Two searches have already been performed. New magnetic material has been found and consequently synthesized by experimental collaborators - Co3Mn2Ge. From the ab-initio calculations, the defect-free material was predicted to have the saturation magnetization of 1.71 T, the uniaxial magnetocrystalline anisotropy of 1.44 MJ/m3, and the Curie temperature of 700 K. Its magnetism depends critically on the amount of disorder of the Co and Ge atoms, a further improvement of the magnetism is possible.

MA 32.8 Thu 16:45 H43

MAELAS: MAgneto-ELAStic properties calculation via computational high-throughput approach — Pablo Nieves[1], Sergiu Arapan[1], Shihao Zhang[2], Andrzej Kadzielawa[1], Ruifeng Zhang[2], and •Dominik Legut[1] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czech Republic — [2]School of Mat. Sci. and Eng., Beihang University, Beijing, China

Magnetostriction is a physical phenomenon in which the process of magnetization induces a change in the shape or dimension of a magnetic material. Nowadays, materials with large magnetostriction are used in many electromagnetic microdevices as actuators and sensors. By contrast, magnetic materials with extremely low magnetostriction are required in applications such as electric transformers. In this work, we present the program MAELAS[1,2] to calculate anisotropic magnetostriction coefficients and magnetoelastic constants in an automated way by quantum-mechanical calculations. The behavior of the magnetocrystalline anisotropy energy and magnetostrictive coefficients under a general external magnetic field could be visualized as a relative length change using our MAELASviewer tool[3]. To verify accuracy and our approach in general we present a number of examples of each crystal symmetry class with calculated magnetostriction and magnetoelastic constants and compare them with recorded data.

References:[1-3] www.md-esg.eu/software and references therein

MA 33: Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)

Time: Thursday 15:00–16:45 Location: H47

MA 33.1 Thu 15:00 H47

Fast non-volatile electrical switching of the magnetoelectric domain states in the cubic spinel Co_3O_4 — •Maximilian Winkler, Somnath Ghara, Korbinian Geirhos, Lilian Prodan, Vladimir Tsurkan, Stephan Krohns, and Istvan Kezsmarki — Universität Augsburg, Augsburg, Deutschland

Here, we investigate the magnetoelectric effect of Co_3O_4 at temperatures far below the Neel-temperature of T_N = 30K. A large magnetoelectric coefficient of up to 14ps/m is achieved if the system is cooled through TN while magnetic and/or electric fields are applied. According to these poling procedures we provide a systematic analysis of how the magnetoelectric domain state can be controlled and even in situ switched by reversing the direction of either the electric or the magnetic field. The complete switching of the antiferromagnetic state is found to be faster than microseconds. Altogether, the control of the magnetoelectric domains and the fast switching dynamics makes the linear magnetoelectric coupling of Co_3O_4 highly interesting for spintronics.

MA 33.2 Thu 15:15 H47

Contribution of charge and strain coupling in artificial multiferroic Fe3O4/PMN-PT heterostructures — •Patrick Schöffmann[1,2], Anirban Sarkar[2], Mai H. Hamed[2], Tanvi Bhatnagar-Schöffmann[3], Sabine Pütter[4], Philippe Ohresser[1], Brian J. Kirby[5], Alexander J. Grutter[5], Juri Barthel[6], Emmanuel Kentzinger[2], Annika Stellhorn[2], Martina Müller[7], and Thomas Brückel[2] — [1]Synchrotron SOLEIL, France — [2]Forschungszentrum Jülich GmbH, JCNS-2 and PGI-4, JARA-FIT, Germany — [3]Centre de Nanoscience et de Nanotechnologies, CNRS, Université Paris-Saclay, France — [4]Forschungszentrum Jülich GmbH, JCNS@MLZ, Germany — [5]NIST Center for Neutron Research, USA — [6]Forschungszentrum Jülich GmbH, ER-C-2, Germany — [7]Fachbereich Physik, Universität Konstanz, Germany

To be able to develop denser and faster data storage and computing solutions artificial multiferroic heterostructures are a promising approach, as they enable direct switching of magnetic states with voltage. We grow ferrimagnetic Fe3O4 thin films on ferroelectric PMN-PT substrates to study the effect of strain and polarisation induced by the substrate onto the magnetic properties of the film. We found that the coupling due to strain and charge is strongly dependent on the orientation of the sample in an external magnetic field as well as the substrate cut. We will present a simple model to explain the contribution of strain and charge for different substrate and magentic field orientations.

MA 33.3 Thu 15:30 H47

Microscopic theory of the THz modes and their nonreciprocal directional dichroism in the antiferromagnet Fe2Mo3O8 — •Kirill Vasin[1,2], Alexey Nurmukhametov[2], Mikhail Eremin[2], Anna Strinic[1], Lilian Prodan[1], Vladimir Tsurkan[1], István

Kézsmárki[1], and Joachim Deisenhofer[1] — [1]Augsburg University, Augsburg, Germany — [2]Kazan, Russia

In the present work, the transmission measurements of a polar dielectric Fe2Mo3O8 were performed by THz time-domain spectroscopy. The origin of the low-lying excitations is not clear, but they were assigned to electromagnons and magnons due to their appearance below TN.

Our microscopic model successfully describes the origin of the optical excitation spectrum in a broad frequency range from the THz to the near-infrared frequency range and the observed dichroism of the low-lying optical modes because of the on-site excitations of the Fe2+ ions in this material. We used the technic of the effective Hamiltonian, including the effects of the crystal field, superexchange interaction and spin-orbit coupling, to model the level schemes of Fe ions projected on the ground configuration of 3d6 electrons.

The directional dichroism in Fe2Mo3O8 can be described by the interference of magnetic and electric-dipole matrix elements, which depend on the applied magnetic field. Our modelled results agrees to the acquired experimental data.

MA 33.4 Thu 15:45 H47

Magnetization reversal through an antiferromagnetic state — •Somnath Ghara[1], Evgenii Barts[2], Kirill Vasin[1], Dmytro Kamenskyi[1], Lilian Prodan[1], Vladimir Tsurkan[1], Maxim Mostovoy[2], Istvan Kezsmarki[1], and Joachim Deisenhofer[1] — [1]Experimentalphysik V, University of Augsburg, Augsburg, Germany — [2]University of Groningen, Groningen, The Netherlands

The polar magnet $Fe_2Mo_3O_8$ has recently attracted tremendous interests due its versatile properties, such as magnetoelectric effect and giant thermal hall effect. This compound has a polar hexagonal (space group $P6_3mc$) structure at room temperature and undergoes a collinear antiferromagnetic ordering of Fe^{2+} moments below $T_N =$ 60 K, accompanied by a large electric polarization besides that of the structural origin. Upon application of (high) magnetic field, a metamagnetic transition from the antiferromagnetic to a ferrimagnetic state takes place. The ferrimagnetic state can also be stabilized by partially substituting Fe^{2+} ions by Zn^{2+} ions. The magnetic symmetry ($6m'm'$) of the ferrimagnetic state is compatible with a linear magnetoelectric effect. In this talk, I will show that at the coercive field of the isothermal reversal of a ferrimagnetic state in $Fe_{1.86}Zn_{0.14}Mo_3O_8$ the pristine antiferromagnetic state re-emerges as a metastable state. The reappearance of the antiferromagnetic state, supported by the theoretical calculations, is reflected in a large change of electric polarization and directly established by the reoccurrence of the characteristic low-energy THz excitation of the AFM state.

MA 33.5 Thu 16:00 H47

Transfer of a domain pattern between ferroic orders — •Yannik Zemp[1], Ehsan Hassanpour[1], Yusuke Tokunaga[2], Yasujiro Taguchi[3], Yoshinori Tokura[3], Thomas Lottermoser[1], Manfred Fiebig[1], and Mads C. Weber[1,4] — [1]Department of Materials, ETH Zurich — [2]University of Tokyo — [3]Riken CEMS, Japan — [4]IMMM, Université Le Mans

In multiferroic materials with two ferroic orders, the order parameters and their respective domain patterns may be rigidly coupled or completely independent, with both of these cases having their merits. We show that in materials with three ferroic order parameters, unusual combinations of coupling and independence are possible. One such material is $Dy_{0.7}Tb_{0.3}FeO_3$. Here, an antiferromagnetic order of the rare earth ions (L) and a ferromagnetic order of the iron ions (M) induce an electric polarisation (P) and a trilinear coupling term $M \cdot L \cdot P$ contributes to the free energy. This coupling term dictates that a reversal of one order parameter needs to be compensated by the product of the other two order parameters to minimise the free energy. Using this fact, we show that a domain pattern in M can be transferred to P while erasing it in the original order parameter, and vice versa, by the application of magnetic and electric fields. We measure the P and M patterns independently by optical second harmonic generation imaging and Faraday rotation microscopy, respectively. The third order parameter L acts as the "memory buffer" for the transfer. The presented work demonstrates the significance of exploration in multiferroics beyond a bilinear coupling.

MA 33.6 Thu 16:15 H47

Magnetoelectric domains and topological defects in hexagonal manganites — •M. Giraldo, Q. N. Meier, A. Bortis, D. Nowak, N. A. Spaldin, M. Fiebig, M. C. Weber, and Th. Lottermoser — Department of Materials, ETH Zurich

Domains and domain walls reflect the different interdependence of magnetic and electric order in multiferroics. For example, in type-II multiferroics, magnetic and electric domain patterns are one-to-one linked, whereas in type-I multiferroics, magnetic and electric domain morphologies can be different, and their coupling no longer mandatory. We show – using experiment and theory – that multiferroics with separately emerging magnetic and electric order can have a strong bulk magnetoelectric coupling even though the leading magnetoelectric cross-coupling is symmetry-forbidden. We show, taking ErMnO3 as example, that the structural distortions that lead to the ferroelectric polarization also break the balance of the competing superexchange contributions. The resulting bulk coupling leads to novel types of topological defects, like magnetoelectric domain walls and multifold vortex-like singularities. We argue that the apparent independence of magnetic and electric orders in type-I multiferroics leads to uncommon phenomena, not open to the type-II class, which can open additional degrees of freedom for the future control of their magnetoelectric functionality [1].

[1] M. Giraldo, Q.N. Meier, A. Bortis et al. Magnetoelectric coupling of domains, domain walls and vortices in a multiferroic with independent magnetic and electric order. Nat Commun 12, 3093 (2021).

MA 33.7 Thu 16:30 H47

Measuring Antiferromagnets with a SQUID Setup in Magnetically Shielded Environments — •Michael Paulsen[1], Jörn Beyer[1], Michael Fechner[2], Ralf Feyerherm[3], Klaus Kiefer[3], Bastian Klemke[3], Julian Lindner[3], and Dennis Meier[4] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany — [4]Norwegian University of Science and Technology, Trondheim, Norway

Antiferromagnets possess zero net dipole magnetization. While predictions of higher order magnetizations have been made for Cr_2O_3, few confirmed measurements exist. In this contribution, we present low-temperature measurements gained on different systems with antiferromagnetic order in very low magnetic backgrounds using a dedicated SQUID setup. In particular, we discuss our results on exterior quadrupolar magnetic fields and relate the distinct quadrupolar magnetic signals to the microscopic spin arrangement in our model systems.

MA 34: Functional Antiferromagnetism

Time: Thursday 15:00–16:45 Location: H48

MA 34.1 Thu 15:00 H48

Giant and tunneling magnetoresistance in unconventional compensated magnets with nonrelativistic d-wave spin-momentum couplings — Libor Šmejkal[1,2], •Anna B. Hellenes[1], Rafael González-Hernández[3], Jairo Sinova[1,2], and Tomaš Jungwirth[2,4] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Czech Academy of Sciences, Prague, Czech Republic — [3]Universidad del Norte, Barranquilla, Colombia — [4]University of Nottingham, United Kingdom

The magnetoresistance effects used in commercial spintronics devices rely on spin current generated by the time-reversal broken band structure of ferromagnets. Realizing counterpart effects with all-antiferromagnetic electrodes has remained experimentally elusive, as conventional compensated antiferromagnets exhibit symmetries combining time-reversal with translation or inversion and thus prohibit nonrelativistic spin-polarized bands and spin currents. Recently, we have predicted large magnetoresistance effects in multilayers with an unconventional compensated magnetic phase[1]. It is characterized by zero magnetization and a time-reversal broken band structure[2], with d-wave spin-momentum coupling and alternating spin polarization [1,3] (thus also referred to as altermagnetism[3]). In the present contribution, we will describe mechanisms for giant and tunneling magnetoresistance relying on the anisotropic and valley-dependent forms of the d-wave spin-momentum coupling[1]. [1] L. Šmejkal, A. B. Hellenes et al., Phys. Rev. X 12, 011028, 2022. [2] L. Šmejkal et al., Sci. Adv. 6, eaaz8809, 2020. [3] L. Šmejkal et al., arXiv:2105.05820v2, 2021.

MA 34.2 Thu 15:15 H48

Exploring the magnetic ground states in different layers of Mn on Ir (111) by SP-STM — •vishesh saxena, arturo rodriguez sota, Roland Wiesendanger, and Kirsten von Bergmann — Institut für Nanostruktur- und Festkörperphysik, Hamburg

Conventional magnetic skyrmions are susceptible to unwanted phenomena such as the skyrmion Hall effect. This is a highly undesirable effect that hinders the application of such skyrmions in spintronic devices. An alternative are antiferromagnetic skyrmions which do not show a skyrmion Hall effect [1]. In the quest to explore systems that can host antiferromagnetic skyrmions, we have studied the magnetism of Mn on Ir (111) using spin-polarized scanning tunneling microscopy (SP-STM). Having an antiferromagnetic spin order on a periodic lattice can induce magnetic frustration. It has already been shown that the magnetic ground states of Mn monolayers on Re (0001) can be the row-wise antiferromagnetic state or the 3Q state depending on the stacking of Mn [2]. In the present work, the magnetic behavior of the monolayer, double layer, and the triple layer of Mn on Ir(111) is studied. Different magnetic ground states are observed depending on the Mn layer thickness.

[1] X. Zhang, Y. Zhou, and M. Ezawa, Antiferromagnetic Skyrmion: stability, creation and manipulation, Scientific Reports 6, 1 (2016). [2] J. Spethmann, S. Meyer, K. von Bergmann, R. Wiesendanger, S. Heinze, and A. Kubetzka, Discovery of magnetic single-and triple-q states in Mn/Re(0001), Physical Review Letters 124, 227203 (2020).

MA 34.3 Thu 15:30 H48

Identification of Néel vector orientation in antiferromagnetic NiO thin films — •Christin Schmitt[1], Luis Sanchez-Tejerina[2], Rafael Ramos[3], Eiji Saitoh[3,4], Giovanni Finocchio[2], Lorenzo Baldrati[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, Italy — [3]WPI-AIMR, Tohoku University, Japan — [4]Department of Applied Physics, The University of Tokyo, Japan

Spintronics using antiferromagnets (AFM) is promising due to intrinsic dynamics in the THz range and the absence of stray fields. However, efficient writing and reading is necessary in terms of applications. Recently, current-induced writing of the Néel order in AFMs has been reported and different switching mechanisms have been put forward [1,2]. The mechanisms depend on the type of domains present. Here, we focus on antiferromagnetic NiO/Pt thin films, and image reversible electrical switching by photoemission electron microscopy (PEEM) employing the x-ray magnetic linear dichroism (XMLD) effect. By varying the x-ray polarization and sample azimuthal angle, we identify the crystallographic orientation of the domains that can be switched and quantify the Néel vector direction, showing that the switching occurs between different T-domains [3]. Finally, we characterize the domain walls showing that they are non-chiral and reveal a large anisotropy in the NiO thin films. [1] T. Moriyama, et al., Sci. Rep. 8, 14167 (2018). [2] P. Zhang, et al., Phys. Rev. Lett. 123, 247206 (2019). [3] C. Schmitt, et al., Phys. Rev. Appl. 15, 034047 (2021).

MA 34.4 Thu 15:45 H48

Magnon Hanle effect in easy-plane antiferromagnets — •Janine Gückelhorn[1,2], Akashdeep Kamra[3], Tobias Wimmer[1,2], Matthias Opel[1], Stephan Geprägs[1], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, BAdW, 85748 Garching, Germany — [2]Physik-Department, TUM, 85748 Garching, Germany — [3]IFIMAC and Departamento de Fisica Teorica de la Materia Condensaga, Universidad Autonoma de Madrid, 28049 Madrid, Spain — [4]Munich Center for Quantum Science and Technology, 80799 München, Germany

Antiferromagnets have drawn much attention due to their unique properties and potential for interesting device applications. In analogy to a spin-1/2 system, antiferromagnetic magnon pairs can be described in terms of a magnonic pseudospin. Recently, first experimental observations of the associated dynamics and the magnon Hanle effect have been reported and described using a 1D pseudospin transport model. Here, we discuss the effects of dimensionality on the magnon spin signal by studying insulating hematite (α-Fe_2O_3) films with varying thickness [1]. For both a thin and a thick film, we find a pronounced signal caused by the magnon Hanle effect. However, the magnonic spin signal exhibits clear differences in both cases. We extend the theoretical description by taking into account low-energy finite-spin magnons and use it to explain our observations. This provides deeper insight into the detailed understanding of magnonic pseudospin dynamics.

[1] J. Gückelhorn *et al.*, Physical Review B **150**, 094440 (2022)

MA 34.5 Thu 16:00 H48

Role of substrate clamping on anisotropy and domain structure in the canted antiferromagnet α-Fe_2O_3 — •Angela Wittmann[1], Olena Gomonay[1], Kai Litzius[2], Alexandra Churikova[3], Norman Birge[4], Felix Büttner[5], Sebastian Wintz[2], Mohamad Mawass[5], Markus Weigand[5], Florian Kronast[5], Jairo Sinova[1], Gisela Schütz[2], and Geoffrey Beach[3] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [3]Massachusetts Institute of Technology, Cambridge, USA — [4]Michigan State University, East Lansing, USA — [5]Helmholtz-Zentrum für Materialien und Energie GmbH, Berlin, Germany

Antiferromagnets are at the forefront of research in spintronics and demonstrate high potential for revolutionizing memory technologies. For this, understanding the formation and driving mechanisms of the domain structure is paramount. In this work, we investigate the domain structure in a thin-film canted antiferromagnet α-Fe_2O_3 using x-ray linear dichroism (XMLD) and spin Hall magnetoresistance (SMR) measurements. We find that the internal destressing fields driving the formation of domains do not follow the crystal symmetry of α-Fe_2O_3 but fluctuate due to substrate clamping. This leads to an overall isotropic distribution of the Néel order with locally varying effective anisotropy in antiferromagnetic thin films. The insights gained from our work serve as a foundation for further studies of electrical and optical manipulation of the domain structure of antiferromagnetic thin films.

MA 34.6 Thu 16:15 H48

Correlation of Atomic Disorder and Anomalous Hall Effect in a Non-Collinear Antiferromagnet — •Berthold H. Rimmler[1], Binoy K. Hazra[1], Holger L. Meyerheim[1], Arthur Ernst[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute for Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [2]Johannes Keppler University, Altenbergerstrβe 69, Linz 4040, Austria

Non-collinear antiferromagnets (NCAFs) such as the well-studied alloy Mn3Sn have compensated triangular magnetic structures with vanishing net magnetization. Due to magnetic symmetry breaking, they can display a large Anomalous Hall Effect (AHE). Measurement of the AHE requires an imbalance of antiferromagnetic domains. Domain structure control by magnetic field or spin torques is possible in Mn3Sn, because crystalline anisotropy induces weak canted moments. In contrast, these moments are not intrinsic to cubic NCAFs. In this work, we investigate the crystallographic, magnetic and magneto-transport properties of thin films of the cubic NCAF Mn3SnN. We find that the manganese atoms can be displaced from their high-symmetry positions. This atomic site disorder correlates with a finite AHE. We employ ab-initio calculations to show that the manganese site displacement can induce canting. In analogy to Mn3Sn, these canted moments may allow for domain structure control leading to the observed AHE. This work provides new insight into the microscopic origin of canted moments in cubic NCAFs and their correlation with the AHE. Our findings have implications for other magneto-transport effects such as the anomalous Nernst effect or the spin Hall effect.

MA 34.7 Thu 16:30 H48

Spontaneous anomalous Hall effect arising from antiparallel magnetic order in a semiconductor — •Ruben Dario Gonzalez Betancourt[1,2,3,4], Jan Zubáč[3,4], Rafael Julian Gonzalez Hernandez[5], Kevin Geishendorf[3], Zbynek Šobáň[3], Gunther Springholz[6], Kamil Olejník[3], Libor Šmejkal[3], Tomas Jungwirth[3,7], Sebastian Tobias Benedikt Goennenwein[1,8], Andy Thomas[1,2], Helena Reichlová[3], Jakub Železný[3], and Dominik Kriegner[1,3] — [1]IFMP, TU Dresden — [2]IFW Dresden — [3]Institute of Physics, AV ČR, Prague — [4]Charles University, Prague — [5]Universidad del Norte, Barranquilla — [6]Semiconductor Physics, JKU Linz — [7]University of Nottingham — [8]University of Konstanz

It is known that collinear antiferromagnets cannot host a spin split band structure and therefore not show any anomalous Hall effect. Following the recent theory development [1], we experimentally show that this paradigm needs to be revised. We theoretically identify and experimentally confirm the symmetry components of the longitudinal and transversal anisotropic magnetoresistance in thin films of the compensated collinear antiferromagnet MnTe. We experimentally find a hysteretic signal odd in magnetic field in the transversal magnetoresistance, i.e. spontaneous anomalous Hall effect [2]. This effect can be rationalized considering nonmagnetic atoms at non-centrosymmetric lattice sites which break additional symmetries and cause a spin splitting in certain parts of the Brillouin zone.

[1] L. Šmejkal et al., Sci. Adv. 6, aaz8809(2020)
[2] R. D. Gonzalez Betancourt et al., (2021) *arXiv:2112.06805*

MA 35: Poster 2

Topics: Magnonics (35.1-35.14), Magnetic Domain Walls (non-skyrmionic) (MA 35.15-35.17), Ultrafast Magnetization Effects (MA 35.18-35.33), Magnetic Relaxation and Gilbert Damping (MA 35.34-35.36), Magnetic Semiconductors (MA 35.37-35.38), Magnetic Heuslers (MA 35.39-35.40), Complex Magnetic Oxides (MA 35.41), Frustrated Magnets (MA 35.42-35.44), Thin Films: Magnetic Coupling Phenomena / Exchange Bias (MA 35.45-35.48), Thin Films: Magnetic Anisotropy (MA 35.49-35.51), Bulk Materials: Soft and Hard Permanent Magnets (MA 35.52), Magnetic Instrumentation and Characterization (MA 35.53-35.59), Magnetic Particles / Clusters (MA 35.60-35.61), Magnetic Information Technology, Recording, Sensing (MA 35.62), Micro- and Nanostructured Magnetic Materials (MA 35.63-35.65), Multiferroics and Magnetoelectric Coupling (MA 35.66-35.67), Surface Magnetism (MA 35.68-35.71), Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions (MA 35.72), Topological Insulators (MA 35.73-35.75), Weyl Semimetals (MA 35.76).

Time: Thursday 16:00–18:00 Location: P4

MA 35.1 Thu 16:00 P4

Magnetic Coupling in Y3Fe5O12/Gd3Fe5O12 Heterostructures — Sven Becker[1], Zengyao Ren[1,2,3], •Akashdeep Akashdeep[1], and Gerhard Jakob[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]Graduate School of Excellence *Materials Science in Mainz* (MAINZ), Staudingerweg 9, Mainz 55128, Germany — [3]School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China

Ferrimagnetic Y3Fe5O12 (YIG) is the prototypical material for studying magnonic properties due to its exceptionally low damping. By substituting the yttrium with the temperature-dependent magnetic moment of gadolinium, we can introduce an additional spin degree of freedom in form of a magnetic compensation point. Here, we study the magnetic coupling in epitaxial Y3Fe5O12/Gd3Fe5O12 (YIG/GIG) heterostructures grown by pulsed laser deposition. The XRD patterns show Laue oscillations and a narrow rocking curve indicating a smooth surface and interface. From bulk sensitive magnetometry and surface-sensitive spin Seebeck effect and spin Hall magnetoresistance measurements, we determine the alignment of the heterostructure magnetization as a function of temperature and external magnetic field. We show that we can control the magnetic properties of the heterostructures by tuning the thickness of the individual layers. These bilayer devices could potentially control the magnon transport analogously to electron transport in giant magnetoresistive devices[1].

[1] H. Wu et.al.; Phys. Rev. Lett. 120, 097205 (2018).

MA 35.2 Thu 16:00 P4

GHz frequency layered antiferromagnets for novel Magnonic computing applications — •Sally Lord and John Gregg — Clarendon Laboratory, Department of Physics, University of Oxford, Parks Road, Oxford, OX1 3PU, United Kingdom

Magnonic computing is a novel computing paradigm that exploits the unusual behaviour of magnons to develop faster, more efficient devices, that have the potential to rival existing CMOS technologies. Antiferromagnetic materials are a prime candidate for such applications, primarily due to their typical THz resonant frequencies, which offer the possibility of creating devices with faster operating speeds. However, studying the THz frequencies of these materials, using conventional electronic methods, is challenging. Layered antiferromagnetic materials offer a promising solution to this challenge, since the weak interlayer coupling results in resonant frequencies that exist in the easily accessible microwave range. Furthermore, these materials can be artificially created by coupling two ferromagnetic layers via a non-magnetic spacer layer to create synthetic antiferromagnet. In this contribution, we report on the experimental setup designed to explore the magnetic properties of such materials.

MA 35.3 Thu 16:00 P4

Towards Integration: On-chip Excitation of Spin Waves using Meander Antennas tailored to practical Applications — •Johannes Greil[1], Martina Kiechle[1], Matthias Golibrzuch[1], Ádám Papp[2], György Csaba[2], and Markus Becherer[1] — [1]Technical University of Munich (TUM), Germany — [2]Pázmány Peter Catholic University, Budapest, Hungary

Albeit spin-wave (SW) computation principles are understood well, integrating SW-based devices makes an efficient excitation of SWs inevitable. Electrical measurements are performed most conveniently with inductive antennas that transfer radio frequency (RF) power into the SW system and pick up the output signals.

We demonstrate the realization of broadband efficient excitation of SWs with meander antennas in a chip-on-platform system. The platform is a PCB that carries the RF signal to a 100nm thin YIG film with metallized bond pads and meander antennas on top. Despite the lower spectral bandwidth of meander antennas compared to CPW structures they have better impedance matching over a wide frequency range and thus provide efficient SW excitation.

We also demonstrate a new design for a dual-wavelength spin wave antenna that consists of a meander structure with two linewidths and gap sizes. Feeding the antenna with two RF frequencies enables for simultaneous excitation of SWs with two wavelengths at one magnetic bias field. Thus, it can be seen as a first realization of purely SW frequency modulation or as the basis for SW-based frequency-division multiplexing (FDM) with two sub-bands.

MA 35.4 Thu 16:00 P4

Non-linear spin waves at low bias fields in $Ni_{80}Fe_{20}$ elements — •Matthias Volz, Rouven Dreyer, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

Magnetic rf fields can be used to excite non-linear spin waves in $Ni_{80}Fe_{20}$ elements at low bias fields. At a certain rf threshold field, spin waves oscillating at odd half-integer multiples of the driving frequency can be excited [1]. Here, the $\frac{3}{2}\omega$ mode is investigated with frequency resolved magneto-optical Kerr microscopy [2]. Specifically we determine the dynamical response at $\frac{3}{2}$ multiple of the driving frequency. By simultaneously detecting real and imaginary parts of the response at $\frac{3}{2}$ of the driving frequency, we reveal phase stable regimes for these $\frac{3}{2}\omega$ non-linear spin wave modes. These modes are investigated as a function of the pump power level, the bias field, and the $Ni_{80}Fe_{20}$ element thickness. We show that a phase stable non-linear regime can be established for $Ni_{80}Fe_{20}$ thicknesses between 10 nm and 20 nm.

[1] H. G. Bauer et al., Nat. Commun. 6:8274 (2015)
[2] R. Dreyer et al., Phys. Rev. Materials 5.6 (2021)

MA 35.5 Thu 16:00 P4

Sensing of magnetic excitations in 2D-materials with NV-spins — •Hossein Mohammadzadeh, Dominik Maile, and Joachim Ankerhold — ICQ and IQST, University of Ulm, Ulm, Germany

Magnetism in two-dimensional (2D) van der Waals (vdW) materials has recently emerged as one of the most promising areas in condensed matter research, with many exciting emerging properties and significant potential for applications ranging from topological magnonics to low-power spintronics, quantum computing, and optical communications [1]. The nitrogen-vacancy (NV) center in diamond is an excellent platform to detect nanoscale signatures in magnetic materials [2]. The spin state of the NV center can be easily initialized and read out in the optical domain and coherently manipulated with microwave fields. Motivated by and in collaboration with recent experimental activities in this direction [3], in this poster we describe the general strategy and first theoretical results. The latter is based on a description of low energy magnetic excitations in terms of a Kitaev-Heisenberg model and the coupling of magnons in the trivial and in the topological phase to single NV-electronic spins.

[1] Qing Hua Wang et al., ACS Nano, 16, 5, 6960-7079 (2022)
[2] Francesco Casola, Toeno van der Sar, and Amir Yacoby. Nat Rev Mater 3, 17088 (2018)
[3] Jörg Wrachtrup et al. Nat Commun 12, 1989 (2021)

MA 35.6 Thu 16:00 P4

Microwave Control of Magnon Transport in Nanostructures — •Franz Weidenhiller[1,2], Janine Gückelhorn[1,2], Manuel Müller[1,2], Hans Huebl[1,2,3], Matthias Althammer[1,2], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology, München, Germany

Magnon transport in magnetically ordered insulators is of great interest for the implementation of magnonic devices. We here present our results on the diffusive magnon transport signal in yttrium iron garnet (YIG) due to the simultaneous excitation of magnons with electromagnetic microwaves. Using E-beam lithography, we pattern two platinum strips on top of the YIG for the injection and detection of magnons. The Pt strips are electrically insulated from an aluminum microwave antenna, which covers both strips and the gap in between. Via the antenna, microwave driven generation of magnons in the active device area through ferromagnetic resonance is possible. We investigate how these microwave injected magnons affect the magnon transport between the two Pt strips. We compare these results to spin pumping experiments using the two Pt strips as electrical detectors. Finally, we discuss relevant magnon relaxation mechanisms in our experiments.

MA 35.7 Thu 16:00 P4

Unidirectional spin wave propagation mediated by $Co_{25}Fe_{75}$-nanogratings — •Christian Mang[1,2], Monika Scheufele[1,2], Manuel Müller[1,2], Johannes Weber[1,2], Vincent Haueise[1,2], Hans Huebl[1,2,3], Matthias Althammer[1,2], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Unidirectional spin wave propagation adds additional functionalities to magnonic devices and their potential application in communication technology. We report the fabrication of $Co_{25}Fe_{75}$-nanogratings via electron beam lithography and DC magneton sputtering on yttrium iron garnet (YIG) thin films. The dipolar magnetic interactions between the $Co_{25}Fe_{75}$-nanogratings and the YIG-film give rise to a finite non-reciprocity of the spin wave propagation in the YIG-film for a collinear magnetization configuration of the $Co_{25}Fe_{75}$-gratings and the YIG-film [1]. By performing spin wave spectroscopy, we study the coupled spin wave modes of the $Co_{25}Fe_{75}$-nanogratings and the YIG thin films in the Damon-Eshbach geometry using a vector network analyzer.

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

MA 35.8 Thu 16:00 P4

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

We present experimental investigations of the spin-wave frequency comb formation in a confined system, a magnetic vortex. The magnetic vortex shows rich spin-wave dynamics like the formation of whispering gallery magnons and non locally induced three-magnon scattering, all with frequencies in the GHz range. Additionally, there is the low frequency gyration of the vortex core itself. The combination of these dynamics on two different time scales inside magnetic vortices, results in the generation of spin-wave frequency combs with their spacing given by the vortex gyration frequency.

Using Brillouin light scattering microscopy, we show that large amplitude excitations of spin waves purely in the GHz range can induce a gyration of the vortex core, which leads to the formation of frequency combs. Analyzing the mode profiles of the sidebands by micromagnetic simulations, shows that the comb is generated via three magnon scattering under conservation of energy and angular momentum.

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MA 35.9 Thu 16:00 P4

Magnetooptical Investigation of non-reciprocal Phonon-Magnon interaction — •Yannik Kunz[1], Michael Schneider[1], Moritz Geilen[1], Torben Pfeifer[1], Matthias Küss[2], Manfred Albrecht[2], Philipp Pirro[1], and Mathias Weiler[1] — [1]Fachbereich Physik und OPTIMAS, TU Kaiserslautern — [2]Institut für Physik, Universität Augsburg

Surface acoustic waves (SAWs) are employed to achieve miniaturization of telecommunication devices, as they live in the Gigahertz-regime with wavelengths on the micrometre scale. The coupling of SAWs with spin waves (SWs) leads to nonreciprocal SAW-propagation, induced by symmetry breaking coupling mechanisms [1]. We investigated the coupling of SAWs, excited by Interdigital Transducers (IDTs), with SWs in a $LiNbO_3/Co_{40}Fe_{40}B_{20}$(10 nm)/SiN(5 nm)-structure using well-established micro-focused Brillouin Light Scattering Spectroscopy and the novel microfocused frequency-resolved magneto-optical Kerr effect with phase resolution, empowered by vector network analysis [2]. We model the magnetic field and angle-dependent SAW-SW- coupling using an extended theoretical model for continuous, viscoelastic Rayleigh-mode SAWs [3] as well as a theoretical model to describe the magneto-elastic coupling [4]. We acknowledge the funding by DFG via project No. 492421737.

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

[2] L. Liensberger et al. IEEE Magn. Lett. 10, 5503905 (2019).
[3] P.K. Currie et al., Q. Appl. Math. 35, (1977).
[4] M. Küß et al., Phys. Rev. Applied 15, 034060 (2021).

MA 35.10 Thu 16:00 P4

Magnon Bose–Einstein condensates in microscopic thermal landscapes — •Franziska Kühn, Matthias R. Schweizer, Georg von Freymann, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany

This contribution is focused on the behavior of a magnon Bose–Einstein condensate (BEC) in artificial magnetization landscapes at the scale of the wavelengths of condensed magnons. In our work, the magnon condensate is created by overpopulation of a magnon gas using microwave parametric pumping. By combining a heating laser with a microscopic phase-based wave front modulation technique, a temperature pattern is imprinted on the yttrium-iron-garnet film sample. Accordingly, the saturation magnetization, on which the dispersion relation of the magnons depends, is shifted. The corresponding spatial variation of the condensate frequency, acting as an artificial potential for the BEC, affects its dynamics and propels magnon supercurrents and Bogoliubov waves. Since the size of these patterns is small compared to the area of BEC formation, it is possible to investigate the BEC in two-dimensional thermal landscapes. In the experiment, by utilizing microfocused Brillouin light scattering spectroscopy, we study the anisotropy of the two-dimensional density distribution of a magnon BEC and the possibility of interference effects between Bogoliubov waves.

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MA 35.11 Thu 16:00 P4

Optical characterisation of direct write 3D nanoarchitectures for magnonics — •Sebastian Lamb-Camarena[1,2], Sabri Koraltan[3], Qi Wang[1], Fabrizio Porrati[4], Sven Barth[4], Michael Huth[4], Michal Urbanek[5], Dieter Suess[3], Andrii Chumak[1], and Oleksandr Dobrovolskiy[1] — [1]University of Vienna, Nanomagnetism and Magnonics, Boltzmanngasse 5, 1090 Vienna, Austria — [2]University of Vienna, Vienna Doctoral School in Physics, Boltzmanngasse 5, 1090 Vienna, Austria — [3]University of Vienna, Physics of Functional Materials, Boltzmanngasse 5, 1090 Vienna, Austria — [4]Physikalisches Institut, Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [5]CEITEC BUT, Brno University of Technology, Brno 61200, Czech Republic

Major directions in magnonics are the extension of magnonic conduits into the third dimension, and operations with short wavelength, fast moving exchange magnons. Both are addressed by direct write nanoarchitectures fabricated by focused electron beam induced deposition (FEBID). Characterisation results of 2D and 3D magnetic FEBID nanostructures by Brillouin light scattering (BLS) spectroscopy and ferromagnetic resonance (FMR) measurements are presented, including a structure with 3D hemicylindrical protrusion along the top face of the rectangular waveguide. The FEBID nanostructures exhibit strong magnetic response to quasi-static and dynamic external magnetic stimuli. Further characterisation of the material properties is foundational for advancing research into spin wave dynamics and geometric curvature induced effects on signal propagation.

MA 35.12 Thu 16:00 P4

VSM and EPR characterization of GGG at ultralow temperatures — •R. O. Serha[1], S. Knauer[1], D. Schmoll[1], K. Davidkova[3], Q. Wang[1], B. Budinská[1], O. V. Dobrovolskiy[1], V. E. Demidov[2], M. Urbánek[3], S. O. Demokritov[2], and A. V. Chumak[1] — [1]University of Vienna, Faculty of Physics, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Boltzmanngasse 5Institute for Applied Physics and Center for Nonlinear Science, University of Muenster, Corrensstrasse 2-4, D-48149 Muenster, Germany — [3]CEITEC BUT, Brno University of Technology, Purkynova 123, 612 00 Brno, Czech Republic

Magnons, the quanta of spin-waves, also exist in paramagnetic materials and are known as paramagnons. Paramagnon properties are governed by the exchange interactions, which do not vanish above Curie/Neel temperature and the dipolar interactions. Here we present our results on the investigation of electron paramagnetic resonance (EPR) spectroscopy in gadolinium gallium garnet (GGG) and DPPH bulk slabs in a wide range of temperatures down to 20 mK. GGG is one of the materials of choice, as Gd^{3+} ions have a large spin S = 7/2 and its saturation magnetization is about $M_s = 800$ kA/m. Millikelvin temperatures allow reaching the saturation of the GGG magnetization, by applying magnetic fields of hundreds mT. However, the EPR linewidth of GGG is strongly influenced by the phenomenon of dipolar broadening, while DPPH is known to have a very narrow resonance line. These studies form an initial step toward investigations of long-propagating paramagnons.

MA 35.13 Thu 16:00 P4

Aharonov-Casher effect in spin-wave refraction — •Andrii Savchenko[1,2], Vladimir Krivoruchko[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Donetsk Institute for Physics and Engineering, National Academy of Sciences of Ukraine, 03028 Kyiv, Ukraine

It has been shown that in a homogeneous magnetic film there is a possibility of electric field control on the reflection and refraction of spin waves at the interface formed by regions under the effect of different electric fields. Under these conditions, the critical angles for Snell's law, the positive or negative refraction of the spin waves, and their non-reciprocity with respect to the incident angle are determined by the electric field. This is possible due to the electrically induced Aharonov-Casher phase shift of the spin-wave phase, that is equivalent to adding a Dzyaloshinskii-Moriya-like interaction between the spins of neighboring ions.

MA 35.14 Thu 16:00 P4

Ring-shaped multi-bandpass spin wave filter — •Takuya Taniguchi, Michael Lindner, Christian Riedel, and Christian Back — Technische Universität München

Spin waves (SWs) are fundamental collective excitations of magnetic order and their wave character makes it possible to potentially realize next generation logic devices. As one of the possible logic devices, multi-bandpass filters are desired in order to forbid certain frequency bands of SWs. In this work, we design a SW wave-guide, which has a ring shape attached to the middle of a stripe. In the device, SWs (SW1s) travel through the stripe part and are split to the ring part and the stripe part at the middle of the stripe. The SWs traveling through the ring (SW2s) interfere with the SW1s after traveling one round and SW1s are suppressed when the phase difference between SW1s and SW2s is pi. We fabricate devices from 200-nanometer-thick YIG films and observe SW propagation using Brillouin light scattering (BLS). Since the phase difference depends on the wavelength of the SWs, we control the wavelength by varying the SW excitation frequency and evaluate the filtering effect. In the presentation, we report the efficiency of the ring-shaped SW filter and provide some key parameters for determining the forbidden frequencies of SWs.

MA 35.15 Thu 16:00 P4

Orientation and Shape of 180° Magnetoelastic Domain Walls in Antiferromagnets — •Bennet Karetta, Olena Gomonay, and Jairo Sinova — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Antiferromagnets are potential candidates to be used in the future for active spintronics elements as they are faster and more stable than the ferromagnets in recent devices. However, without a net magnetization it is more difficult to manipulate their magnetic state. Recent studies suggested that the magnetoelastic coupling can be used to overcome this problem. Thus, it is essential to understand the interaction between the strains in the antiferromagnet and the Néel vector. In this study, we investigate the 180° antiferromagnetic domain wall and the influence on it from the strains. It is known that non-180° domain walls have preferred alignments in antiferromagnets since strains in the respective domains are incompatible for certain orientations. We show, that there is a similar anisotropy for the orientation of 180° domain walls, which now is induced by incompatibilities at the domain wall itself. We further investigate this anisotropy to determine how magnetoelasticity affects the shape of the closed 180° domain wall loop in the antiferromagnet. With this, we demonstrate that the shape of the loop significantly changes in comparison to a purely magnetic system and thus verify the strong influence of the magnetoelastic coupling on the equilibrium domain structure.

MA 35.16 Thu 16:00 P4

Current-induced Creation of domain walls in synthetic antiferromagnets — Robin Msiska[1], •Omer Fetai[1], Raphael Kromin[2], Davi Rodrigues[3], and Karin Everschor-Sitte[1,4] —

[1]Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Mainz — [3]Politecnico di Bari, Bari, Italy — [4]Center for Nanointegration Duisburg- Essen (CENIDE)

Improvements in the storage capacity of modern-day memory devices are slowing down and new concepts for storing data are required. A suggestion for a three-dimensional data storage is the racetrack memory which stores information in terms of magnetic domains. The use of synthetic antiferromagnets (SAF), i.e., antiferromagnetically coupled ferromagnetic bilayer systems, accelerates the information access time because the domain walls can be moved up to ten times faster [1]. To obtain a market-ready device, many challenges must be overcome, one of which is integrating a controlled domain wall write process into SAFs. We study the controlled creation of domain walls in SAFs by electrical means. In the case of spin-transfer torques, we find a critical current strength above which antiferromagnetic domain walls are created from an inhomogeneity. In contrast to the ferromagnetic case[2] we show that the critical current density is an order of magnitude higher.

[1] S. Parkin, S-H. Yang, Nat. Nanotechnol. 10, 195 (2015)
[2] M. Sitte et al. Phys. Rev. B 94, 064422 (2016)

MA 35.17 Thu 16:00 P4

Magnetization patterns in biaxial Fe32Co68 core-shell nanostructures with hexagonal cross-section — •Anastasiia Korniienko[1], Alexis Wartelle[2], Matthias Kronseder[3], Michael Foerster[4], Miguel Ángel Niño[4], Sandra Ruiz-Gomes[4], Muhammad Waqas Khaliq[4,5], and Christian H. Back[1] — [1]Technical Univ. of Munich, Garching, Germany — [2]Univ. Grenoble Alpes, Grenoble, France — [3]Univ. of Regensburg, Regensburg, Germany — [4]Alba Synchrotron Light Facility, CELLS, Barcelona, Spain — [5]Univ. of Barcelona, Barcelona, Spain

We fabricate nanostructures with a Fe32Co68 shell on GaAs nanorods with hexagonal cross-section. Such a FeCo alloy, deposited on the (110) GaAs planes (the rod's facets), shows a thickness-dependent spin-reorientation transition [1]. At a thickness of 32 monolayers, we expect our tube walls to feature a biaxial behavior, with distinct azimuthal components of magnetization. Here we use Photoemission Electron Microscopy in combination with X-ray Magnetic Circular Dichroism (XMCD-PEEM) to image the magnetic configuration of individual nanostructures [2]. The XMCD-PEEM imaging was done at remanence, between applications of magnetic fields and for different angles between the x-rays and the tube axis. Some of our nanostructures feature a large number of unexpectedly persistent magnetic domains. We observed a switching between almost longitudinal and azimuthal magnetization for some domains, confirming system's biaxial behavior.

[1] Muermann et al., J. Appl. Phys., 103, 07B528 (2008).
[2] Wyss et al., PRB 96, 024423 (2017).

MA 35.18 Thu 16:00 P4

Exploring transient ferromagnetism in $La_{0.9}Sr_{0.1}MnO_3$ thin films — •Karen P. Stroh, Tim Titze, Henrike Probst, Stefan Mathias, Daniel Steil, and Vasily Moshnyaga — I. Physikalisches Institut, Georg-August-Universität Göttingen

In perovskite manganites such as $La_{1-x}Sr_xMnO_3$ (LSMO), complex phase diagrams with different magnetic, electric, and structural phases are obtained as a function of chemical doping. Whilst $x = 0.33$ is referred to as optimal doping, underdoped LSMO with $x \sim 0.1 - 0.15$ is close to a PM-I/FM-M phase boundary for $T>T_C$ [1] and thus a suitable candidate for photo-induced transitions. Ultrafast laser pulses may photoionize electrons from Mn^{3+} to Mn^{4+}, establishing a double exchange interaction and a FM state, so that the compositional phase boundary might temporarily also be crossed via "optical" doping [2].

Underdoped LSMO/$SrTiO_3$(100) thin films were epitaxially grown by metalorganic aerosol deposition (MAD) and investigated by time-resolved magneto-optical Kerr effect (MOKE) and pump-probe reflectivity (PPR). Temperature-, fluence-, and magnetic field-dependent measurements have been performed on timescales from femtoseconds to nanoseconds using a pulsed fs laser setup. Our results indicate a possibility to optically drive a paramagnetic-insulating LSMO into a transient ferromagnetic state above T_C on a sub-ps timescale.

Financial support by the DFG via Project 399572199 and within the SFB 1073 (TP A02) is acknowledged.

[1] Hemberger et al., Physical Review B 66, 094410 (2002)
[2] Matsubara et al., Physical Review Letters 99(20), 207401 (2007)

MA 35.19 Thu 16:00 P4

Influence of metallic substrates on the OISTR effect in permalloy thin films — •Martin Anstett[1], Simon Häuser[1], Jonas Hoefer[1], Laura Scheuer[1], Philipp Pirro[1], Burkard Hillebrands[1], Benjamin Stadtmüller[1,2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

Optical manipulation of magnetic materials on extremely short, sub-100 fs timescales can be achieved either by generation and injection of optically induced (ballistic) spin currents or by direct excitation of the spin system, for instance by the optically induced spin transfer (OISTR) effect as shown in [1, 2].

In this work, we aim to reveal the mutual interplay of these spin-transfer effects on ultrafast timescales. Therefore, we investigate the ultrafast demagnetization of a thin $Fe_{20}Ni_{80}$ alloy on a non-magnetic Au substrate and how it is influenced by the spin-dependent charge transport into the Au substrate. As an element-resolved probe of the spin dynamics, we employ time-resolved Kerr spectroscopy with fs-XUV radiation in transversal geometry to disentangle the spectroscopic signatures of the OISTR and ballistic spin transport in this material. Our results will be compared to the magnetization dynamics of a $Fe_{20}Ni_{80}$ film on an insulating substrate.

References: [1] Dewhurst et al.; Nano Lett., 2018; 18: 1842*1848 [2] Hofherr et al., Sci. Adv., 2020; 6: eaay8717

MA 35.20 Thu 16:00 P4

Ultrafast magnetization dynamics in perovskite manganites — •Maren Schumacher, Henrike Probst, Mariana Brede, Christina Möller, Karen Stroh, Tim Titze, Cinja Seick, Sabine Steil, Marcel Reutzel, G. S. Matthijs Jansen, Daniel Steil, Vasily Moshnyaga, and Stefan Mathias — 1. Physikalisches Institut, Göttingen, Germany

Correlated manganese oxides are promising materials to realize new functionalities in spintronic applications, which are enabled by strong correlations between electrons, lattice, and spins. Femtosecond time-resolved spectroscopy has proven to be a powerful probe of these interactions. Here, we study demagnetization dynamics in thin-film perovskite manganites using magneto-optical Kerr spectroscopy (MOKE) in the visible and extreme ultraviolet (XUV) range of the spectrum. This allows us to study the samples as a function of temperature (T=10 - 400 K), magnetic field (up to B=1 T), and, in the case of using XUV probe light, with element-specificity. We will show first results of element-specific HHG-MOKE data on high-quality manganite thin film of LSMO and compare it to standard visible-MOKE.

MA 35.21 Thu 16:00 P4

Wide spectral range ultrafast pump-probe magneto-optical spectrometer at low temperature, high-magnetic and electric fields — •Fabian Mertens[1], Marc Terschanski[1], David Mönkebüscher[1], Stefano Ponzoni[1], Davide Bossini[1,2], and Mirko Cinchetti[1] — [1]Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany — [2]Department of Physics and Center for Applied Photonics, University of Konstanz, Germany.

We developed a table-top setup to perform magneto-optical pump-probe measurements with the possibility to independently tune the photon-energy of both pump and probe beams in the 0.5 eV - 3.5 eV range[1]. Our apparatus relies on a commercial turn-key amplified laser system, able to generate light pulses with duration shorter than or comparable to 100 fs throughout the whole spectral range. The repetition rate of the source can be modified via the computer in the 1 kHz - 1 MHz range. A commercial balanced detector is connected to a high-frequency digitizer, allowing for a highly-sensitive detection scheme: rotations of the probe polarization as small as 70 μdeg can be measured. Additionally, a DC magnetic field as high as 9 T and voltages in the kV regime can be applied on the sample. A cryostat allows us to precisely set the temperature of the sample in the 4 K - 420 K interval. We test the performance of our setup by measuring the ultrafast demagnetization of a cobalt crystal as a function of a wide variety of experimental parameters.

[1] F. Mertens et al., *Review of Scientific Instruments* **91** (2020)

MA 35.22 Thu 16:00 P4

Integration of a supercontinuum probe line in a setup for time-resolved magneto-optical spectroscopy — •Sophie Bork, Richard Leven, Marc Terschanski, Fabian Mertens, Umut

Parlak, and Mirko Cinchetti — Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

We have recently developed a setup for wide spectral range ultrafast pump-probe magneto-optical spectroscopy at low temperature, high-magnetic and electric fields [1]. Here we present an upgrade of this setup that allows to measure the transient reflectivity (ΔR/R) in a broad spectral range and with femtosecond time-resolution. To this end, we have generated a broadband supercontinuum (white light) probe beam that covers the wavelengths from the near UV to the near IR region. The detection of the white light spectrum reflected or transmitted from the sample is achieved by a 1D-array of CMOS detectors that allow for simultaneous data acquisition of all available wavelengths. This upgraded setup can work at high repetition rates ($<$ 100 kHz) and allows to perform measurements with high temporal and spectral resolution. This is particularly useful, for example, to fully map the photo-driven transient evolution of the band gap energy in magnetically ordered semiconducting systems and to assess whether it is linked to the magnetization dynamics [2]. In this poster contribution we will present all technical details of the setup together with first characterization measurements to specify its performance.

[1] Mertens et al., Rev. Sci. Instrum. 91, 113001 (2020)
[2] Bossini et al., Phys. Rev. B 104, 224424 (2021)

MA 35.23 Thu 16:00 P4

All-optical switching of magnetically hard CoPt and $L1_0$-FePt in contact with a Gd-layer — •Johannes Seyd[1], Julian Hintermayr[2], Manfred Albrecht[1], and Bert Koopmans[2] — [1]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany — [2]Department of Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

All-optical switching (AOS) by single femtosecond laser pulses promises to be an ultrafast, energy-efficient alternative to conventional writing in magnetic recording using magnetic fields. $L1_0$-FePt is a magnetic material with high perpendicular magnetic anisotropy (PMA), which makes it an interesting candidate for future ultrahigh-density magnetic recording applications, and for which helicity-dependent multi-shot AOS has already been confirmed [1].

Thermally-induced single-shot AOS is not only possible in ferrimagnetic alloys with a compensation temperature near room temperature, but also in synthetic ferrimagnets consisting of a ferromagnetic (multi-) layer in contact with a Gd layer, as shown for Co and Co/Ni [2]. These results suggest the possibility of reproducing the same kind of switching in other magnetic thin films, which in the case of L10-FePt would circumvent the problem of writing the magnetically hard material in magnetic recording applications.

We show the most recent results on the thermally-induced AOS behaviour of thin CoPt and $L1_0$-FePt films in contact with a Gd layer.

[1] R. John et al., Scientific Reports 7, 4114 (2017)
[2] M. Beens et al., Physical Review B 100, 220409(R) (2019)

MA 35.24 Thu 16:00 P4

Magnetic field-dependent ultrafast control of an antiferromagnet — •A. Arora[1,4], Y.W. Windsor[6], S.E. Lee[1], J. Sarkar[1], K. Kliemt[3], Ch. Schüssler-Langeheine[2], N. Pontius[2], C. Krellner[3], D.V. Vyalikh[5], and L. Rettig[1] — [1]FHI der MPG, Berlin — [2]HZB für Materialien und Energie GmbH, Berlin — [3]Phy. Inst., Goethe-Uni., Frankfurt am Main — [4]Fach. Phy., FU Berlin — [5]DIPC, Basque, Spain — [6]IOAP, TU Berlin

Antiferromagnets, due to their zero net magnetization, offer faster manipulation of spins and more robust devices. But this also makes the interaction with magnetic order challenging. One way to achieve this is to utilize the magnetic anisotropy to manipulate the spin arrangement which we demonstrated recently using ultrafast optical excitation [1]. For practical applications, understanding the interaction of this effect with external magnetic fields is of strong interest. To this end, we perform time-resolved resonant soft X-ray diffraction in the prototypical A-type antiferromagnet $GdRh_2Si_2$. Consistent with our previous study, we observe a coherent rotation of the antiferromagnetic (AF) arrangement of Gd 4f spins followed by oscillations of the AF order as a consequence of a light-induced change in the anisotropy potential. Surprisingly, upon increasing magnetic field, the frequency of the oscillations as well as the extent of demagnetization upon photoexcitation increases. These observations indicate a change in the magnetic anisotropy potential and may offer a new way towards deterministic control of spin order using combined electromagnetic and magnetic fields. [1] Windsor et al. Commun Phys 3, 139 (2020)

MA 35.25 Thu 16:00 P4

Studying double pulse toggle switching of GdFe — •Rahil Hosseinifar[1], Ivar Kumberg[1], Sangeeta Thakur[1], Evangelos Golias[1], Sebastien Hadjadj[1], Jendrik Gördes[1], Jorge Torres[1], Florian Kronast[2], Mario Fix[3], Manfred Albrecht[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14,14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Switching of magnetization without the help of a magnetic field by using an ultra-fast laser pulse is a popular topic for both applied and fundamental research. We study the effect of double-pulse optical excitation on all-optical toggle switching in $Gd_{26}Fe_{74}$ ferrimagnetic alloys with perpendicular magnetic anisotropy by X-ray magnetic circular dichroism photoelectron emission microscopy. Varying the temporal separation of the two pulses and their intensities reveals a lowering threshold for toggle switching compared to a single pulse, and the formation of three areas in the footprint of the laser pulses for time delays below 1 ps. First, an area is located at lower fluences that does not switch. The second area is at higher fluences where multi-domain nucleation is observed, and the third area is in between and switches deterministically. The experiment is done starting from either a saturated state or in presence of magnetic domains. In both cases, a deterministically switching area is observed which would be desirable for many applications.

MA 35.26 Thu 16:00 P4

Magneto-optical study of proximity effects at the EuO/Co interface — •David Mönkebüscher[1], Paul Rosenberger[1,2], Davide Bossini[1,2], Umut Parlak[1], Martina Müller[2], and Mirko Cinchetti[1] — [1]Department of Physics, TU Dortmund University, Germany — [2]Department of Physics, University of Konstanz, Germany

Europium monoxide has shown great potential as a magnetic insulator and was succesfully employed in various spintronic applications as a spin filter with nearly 100% spin polarized currents [1]. For the use in practical applications, an increase of its relatively low Curie temperature ($T_C = 69\,K$) is necessary. One approach relies on proximity effects, i.e. the coupling with a high T_C ferromagnetic layer [2]. Following this approach, we prepared YSZ/EuO/Co multilayers using molecular beam epitaxy (MBE) [3], and studied them using the magneto-optical setup described in Ref. [4]. First, we measured static hysteresis to gain insight about the nature of the proximity-induced coupling of the two magnetic sublattices. Then we used that the pump-probe experimental scheme to manipulate this coupling by varying the pump laser fluence and the delay between the pump and the probe beam.

[1] T. Santos et al., Phys. Rev B **69**, 241202 (2004)
[2] S. Pappas et al. Sci Rep **3**, 1333 (2013).
[3] P. Rosenberger et al. Phys. Rev. Mater. **6**, 044404 (2022).
[4] F. Mertens et al. Rev. Sci. Instrum. **91**, 113001 (2020).

MA 35.27 Thu 16:00 P4

Wavelength-dependent magnetization dynamics in Ni|Au heterostructures — •Stephanie Roden[1], Christopher Seibel[1], Marius Weber[1], Martin Stiehl[1], Sebastian T. Weber[1], Martin Aeschlimann[1], Benjamin Stadtmüller[1,2], Hans Christian Schneider[1], and Baerbel Rethfeld[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany

For a long time, the ultrafast magnetization dynamics of ferromagnets has predominantly been studied for optical excitation using only one photon energy. However, recent experiments have shown that the dynamics of the demagnetization and remagnetization process can be altered by the wavelength of the exciting laser pulse [1, 2].

In this contribution, we extend the temperature-based μT-model to investigate the ultrafast magnetization dynamics of Ni|Au heterostructures. Our model is based on realistic densities of states of both materials and includes energy and spin transfer at the interface. Thereby, we explicitly consider the wavelength- and layer-dependent absorption profile within multilayer structures. This allows us to show the influence of the wavelength-dependent excitation on the magnetization dynamics [3], which is also affected by the substrate thickness.

References:

[1] V. Cardin *et al.*, Phys. Rev. B 101, 054430 (2020)
[2] U. Bierbrauer *et al.*, JOP: Cond. Mat. 29, 244002 (2017)
[3] C. Seibel *et al.*, arXiv:2112.04780 (2021)

MA 35.28 Thu 16:00 P4

Optical manipulation of the antiferromagnetic order in a Pt/NiO bilayer system by ultrafast energy transfer — •Paul Herrgen[1], Stephan Wust[1], Christopher Seibel[1], Hendrik Meer[2], Christin Schmitt[2], Lorenzo Baldrati[2], Rafael Ramos[3], Takashi Kikkawa[4], Eiji Saitoh[4], Olena Gomonay[2], Jairo Sinova[2], Yuriy Mokrousov[2], Hans Christian Schneider[1], Mathias Kläui[2], Baerbel Rethfeld[1], Benjamin Stadtmüller[1,2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [3]CIQUS, Departamento de Química-Física, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [4]Department of Applied Physics, The University of Tokyo, Tokyo 113-8656, Japan

Antiferromagnets are promising materials for future spintronic devices due to their resilience against external magnetic fields and their high frequency magnon modes. Here, we explore the subpicosecond magnetization dynamics of the antiferromagnet NiO after strong optical excitation with fs light pulses. We find a clear reduction of the magnetic order for a Pt/NiO bilayer systems on sub-picosecond timescales. Our observations are discussed in the framework of an extended μT model. We conclude that the ultrafast loss of antiferromagnetic order in the Pt/NiO bilayer system is mediated by a highly efficient energy transfer between the hot Pt electrons and the NiO spins.

MA 35.29 Thu 16:00 P4

Spin-transport-driven ultrafast magnetization dynamics in a ferrimagnetic Gd/Fe bilayer — •Huijuan Xiao, Bo Liu, and Martin Weinelt — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195, Berlin

Laser-induced spin transport has been proven to be a key ingredient in ultrafast spin dynamics, such as femtosecond demagnetization and all-optical switching (AOS). We use time- and spin-resolved photoemission spectroscopy of the gadolinium surface state to study spin dynamics in a ferrimagnetic Gd/Fe bilayer. This prototype system for AOS was epitaxially grown on W(110). Our findings suggest that spin transport between the antiferromagnetically coupled gadolinium and iron layers leads to an ultrafast drop of the spin polarization and an increased exchange splitting at the Gd surface. The Gd surface state shows an ultrafast decrease of the spin polarization by 20% within the first $\sim$ 100 fs and a subsequent slower decrease by about 5% on the picosecond timescale. The increase of the exchange splitting counterbalances the overall demagnetization of the Gd layer. In contrast, the pure Gd/W(110) film shows a constant spin polarization and a reduced exchange splitting of the surface state upon optical excitation. These findings are corroborated by the transient electron temperature. Our results provide clear evidence that magnetization dynamics in the Gd/Fe bilayer can be driven by spin transport. We see distinct signatures in the spin-dependent electronic structure that allow us to gain microscopic insights into ultrafast spin dynamics (supported by SFB/TRR 227 Ultrafast Spin Dynamics).

MA 35.30 Thu 16:00 P4

Ultrafast demagnetization of 2d ferromagnets — •Nele Stetzuhn[1,2], Felix Steinbach[1], Martin Borchert[1], Abhijeet Kumar[2], Denis Jagodkin[2], Clemens von Korff Schmising[1], Stefan Eisebitt[1], and Kirill Bolotin[2] — [1]Max-Born-Institut, Max-Born-Straße 2 A, 12489 Berlin — [2]Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin

Two-dimensional ferromagnets are one of the latest additions to the family of 2d materials and offer a new platform to study ultrafast magnetic phenomena. When combining 2d ferromagnets with other 2d materials such as transition metal dicalchogenides (TMDs), the absence of lattice mismatch between layers also makes the resulting heterostructures promising for high-performance spintronic devices. Here, we measure the ultrafast demagnetization of 2d ferromagnets with the structure Fe_xGeTe_2 ($x = 3, 5$) after excitation by a pump laser using time-resolved MOKE. The usually low Curie temperature of Fe_xGeTe_2 ($x = 3, 5$) can be increased above room temperature, e.g. by doping with Ni, allowing us to do element-resolved demagnetization measurements at the free-electron laser facility FERMI. This can give insight into effects such as optical inter-site spin transfer (OISTR) in the material.

MA 35.31 Thu 16:00 P4

Heat capacities and Curie curve in the Stoner and Heisenberg models — •Nabil Makadir, Stephanie Roden, Sanjay Ashok, Sebastian T. Weber, Felix Dusabirane, H. Christian Schneider, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany

The excitation of a metallic ferromagnet with an ultrashort laser pulse leads to a demagnetization on the femtosecond timescale. The response of the material is governed by macroscopic properties, like the heat capacities and the equilibrium magnetization (Curie curve). They can be calculated for instance with either the Stoner model or the Heisenberg model. The former attributes the change of magnetization to the shifting of the spin-resolved density of states. The latter describes the reduction of the magnetization through collective angular oscillation of the individual magnetic moments.

In this contribution, we derive the temperature-dependent heat capacities and the Curie curves for Nickel. We compare the results of the Stoner and the Heisenberg model and analyze the advantages and drawbacks of both approaches. Finally, we investigate the transition between Stoner and Heisenberg excitations.

MA 35.32 Thu 16:00 P4

Hybrid simulation tracing non-equilibrium spin-dynamics and -transport — •Lukas Jonda, Johan Briones, Sebastian T. Weber, Christopher Seibel, Sanjay Ashok, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany

We simulate the complex phenomena arising in a magnetic film after femtosecond laser irradiation with help of a hybrid model. This model consists of a combination of two methods: The μT model [1] and a kinetic Monte Carlo method [2]. The former treats the low-energetic electrons as an ensemble, tracing spin resolved temperatures and chemical potentials, as well as their gradients [3]. The latter traces individual high-energetic non-equilibrium electrons, including spin-dependent scattering processes and spin-flip probabilities. We present first investigations of how non-equilibrium electrons influence the magnetization dynamics for Nickel.

The long-term perspective of this project is to develop a model that can describe both the transport of the electron ensemble and individual high-energetic super-diffusive electrons. This allows to study the different types of non-equilibrium transport and their effects on magnetization dynamics.

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[3] S. Ashok et al., Appl. Phys. Lett. **120**, 142402 (2022).

MA 35.33 Thu 16:00 P4

Ultrafast Tunnel Magnetoresistance — •Thomas Jauk[1], Kazma Komatsu[1], Hana K. Hampel[1], Jana Kredl[2], Jakob Walowski[2], Florian Lackner[1], Sangeeta Sharma[3], Markus Münzenberg[2], and Martin Schultze[1] — [1]Institute of Experimental Physics, Graz University of Technology, Graz, Austria — [2]Institute of Physics, University of Greifswald, Greifswald, Germany — [3]Max Born Institute, Berlin, Germany

Magnetic tunnel junctions (MTJ) have been arousing ongoing interest due to their peculiar spin-transfer mechanism since the discovery of the large tunnel magnetoresistance. However, a complete microscopic understanding of the underlying physics is still lacking. We put the spotlight on the interface between a MgO-based tunnel barrier and a CoFeB wedge-like electrode in order to disentangle intertwined phenomena which come along with ultrafast demagnetization. By employing circularly-polarized visible light pulses and utilizing magnetic circular dichroism in a two-photon-photoemission (2PPE) experiment we establish a direct route to the buried interface, providing insight into the spatial arrangement and the electronic behaviour of the magnetic pattern near the Fermi level. Beside the typical demagnetization curve we observe a light-induced increase in magnetic moment for specific energy/momentum intervals. Together with DFT calculations we try to shed light on the microscopic processes involved in the ultrafast demagnetization and, especially, emphasize on the peculiarity of MTJs acting as an energy- and spin-filter.

MA 35.34 Thu 16:00 P4

Ferromagnetic resonance study of spin pumping in epitaxial

Fe/Rh bilayers — •Jonas Wiemeler, Ali Can Actas, Michael Farle, and Anna Semisalova — Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany

The alloy FeRh has been studied extensively for structural, electrical and magnetic properties. On the other hand spin dynamics in a Fe/Rh thin film bilayer system in detail has not been addressed yet. In this work, 5 nm Fe films capped with Rh of thicknesses (0, 1, 2, 3, 5, 10, 15) nm were grown on GaAs(100) substrates using molecular beam epitaxy (MBE). Ferromagnetic resonance (FMR) experiments at room temperature, utilising both angular X-Band and frequency dependence (1-40GHz), were used to characterise the magneto dynamic properties of these bilayers. The growth characteristics of Rh on a 5 nm substrate Fe layer have been investigated using Auger electron spectroscopy (AES) measurements during the Rh growth. It was found, that Rh grows epitaxially on Fe in a layer-by-layer manner. The thickness dependence of the magnetisations precession damping, measured using FMR, shows an exponential behaviour which was analysed in terms of a spin pumping effect. We found, that the spin pumping efficiency of Rh is comparable to Pt, while the spin flip rate compares to that of Pd.
Funding by DFG Project No. 392402498 (SE 2852/1-1 | AL 618/37-1) and helpful discussion with R. Meckenstock and T. Strusch are acknowledged.

MA 35.35 Thu 16:00 P4

Magnetization dynamics of γ-Fe_2O_3 thin films with reduced effective magnetization — •Monika Scheufele[1,2], Manuel Müller[1,2], Janine Gückelhorn[1,2], Luis Flacke[1,2], Andreas Haslberger[1,2], Mathias Weiler[3], Hans Huebl[1,2,4], Stephan Geprägs[1], Rudolf Gross[1,2,4], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Fachbereich Physik und Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Magnetic insulators (MI) are of key importance in the emerging fields of magnonics and spin-caloritronics. In this respect, the room-temperature MI γ-Fe_2O_3 is a promising candidate offering a variety of application perspectives. Here, we report on the static and dynamic magnetic properties of pseudomorphic-grown γ-Fe_2O_3 thin films on MgO (001). We find a strain-induced small effective magnetization $M_{\rm eff}$, showing a sign change at 200 K. In addition, we also observe the impact of slowly relaxing impurities to the ferromagnetic resonance (FMR) field and the linewidth as a function of temperature. Moreover, above 150 K we detect an increase of the FMR linewidth, which we attribute to valence-exchange damping induced by Fe^{2+}-ions in γ-Fe_2O_3 [1].
[1] M. Müller *et al.*, arXiv:2204.11498.

MA 35.36 Thu 16:00 P4

Spin pumping in embedded lateral nanostructures in Fe60Al40 — Tanja Strusch[1], Ralf Meckenstock[1], Rantej Bali[2], Jonathan Ehrler[2], Kay Potzger[2], Kilian Lenz[2], Jürgen Lindner[2], Michael Farle[1], and •Anna Semisalova[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany

The magnetic properties of an Fe60Al40 (FeAl) alloy are tailorable from paramagnetic (PM) to ferromagnetic (FM) state by variation of the structure through ion beam irradiation, making it a promising material for the fabrication of magnetic landscapes and magnonic crystals. Here, we report on ferromagnetic resonance (FMR) detected spin pumping in FeAl/Pd and Py/FeAl bilayers and laterally patterned nanostructures and show that FeAl can be used as spin source and as spin sink. Using FMR, we estimate the spin pumping efficiency and find a spin-mixing conductance of g_FeAl=2.1(+/-0.2) nm^(-2) and a spin diffusion length of λ_FeAl=11.9(+/-0.2) nm for paramagnetic FeAl, and g_Pd=3.8(+/-0.5) nm^(-2) and λ_Pd=9.1(+/-2.0) nm for Pd. Further, we investigate the spin pumping in laterally patterned FeAl nanostructures representing 500 nm wide FM strips separated by PM strips of different width (100-400 nm) produced in a 40 nm thick FeAl film. We find an enhancement of the damping parameter with decreasing width of the PM FeAl areas due to an increase of the number of FM/PM interfaces. Financial support from DFG is gratefully acknowledged (project No. 392402498 (SE 2852/1-1 | AL 618/37-1)).

MA 35.37 Thu 16:00 P4

Growth optimization of ferromagnetic gadolinium nitride (GdN) thin films for magnon transport phenomena — •Raphael Hoepfl[1,2], Manuel Müller[1,2], Matthias Opel[1], Stephan Geprägs[1], 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 (MCQST), München, Germany

Ferromagnetic (FM) semiconductors are of great interest for spintronics devices. Gadolinium nitride (GdN) is one candidate for a semiconducting ferromagnet with a Curie temperature $T_{\rm C}$ of 65-70 K [1]. In this study, we investigate the static and dynamic properties of FM GdN thin films by SQUID magnetometry and broadband ferromagnetic resonance experiments in a cryogenic environment. In detail, we prepare tantalum nitride (TaN)/GdN/TaN thin films on thermally oxidized Si substrates using DC magnetron sputtering, where the TaN is used as seed and protective top layer. Here, we discuss the impact of the various deposition parameters, such as deposition pressure, temperature, rate and reactive N_2 gas flow on the static and dynamic magnetic properties of GdN.
[1] W. B. Mi et al., Appl. Phys. Lett. **102**, 222411 (2013).

MA 35.38 Thu 16:00 P4

Spin polarized band engineering for spin-photocatalyst in ZnO nanowires — Hua Shu Hsu[1], Jun-Xiao Lin[1], •Jutatip Thaomonpun[1], Wei-Jhong Chen[1], Shih Jye Sun[2], and Zdenek Remeš[3] — [1]No. 4-18, Minsheng Road, PIngtung City, 90044, Taiwan (R.O.C.) — [2]700, Kaohsiung University Rd., Nanzih District, Kaohsiung 811, Taiwan(R.O.C.) — [3]Na Slovance 1999/2, Praha 8, Czech Republic

Transition metal-doped oxides with spin-polarization energy bands have been expected as potential materials for semiconductor spintronics applications. In our work, we found that through surface-doped Co/ZnO nanowires (NWs), the generation of spin-polarized energy bands can be confirmed in the ultraviolet (UV) region by magnetic circular dichroism measurements. Because ZnO itself can be applied in the UV photocatalytic material. Therefore, the magnetic field-enhanced photocurrent and magnetic field-enhanced photocatalytic effect due to modulation of the spin-polarized energy band can be observed. And spin-polarized energy band engineering can be extended to non-magnetic ion-doped ZnO NWs. The realization of these spin photocatalytic effects will also provide new opportunities for the study of spin-polarized energy bands in semiconductors.

MA 35.39 Thu 16:00 P4

Electric transport properties of Ni-Mn-In alloy exposed to external stimuli — •Sergiy Konoplyuk[1] and Alexandr Kolomiets[2] — [1]Institute of magnetism of NASU and MESU, Kyiv, Ukraine — [2]Department of Physics, Lviv Polytechnic National University, Lviv, Ukraine

The polycrystalline Ni45.4Mn40In14.6 Heusler alloy was studied to find dominant factors affecting its electric transport behavior in austenitic and martensitic phases. Analysis of three main contributions into temperature dependent resistivity has shown that prevalent mechanisms of carrier scattering in the austenitic phase are scattering on structural and magnetic disorders rather than on thermal fluctuations.

In spite of the small transformation volume effect of 0.09 %, application of hydrostatic pressure of 2 GPa results in almost threefold rise in the longitudinal resistivity and twofold rise in the Hall resistivity due to the pressure-induced martensitic transformation. The measurements of the ordinary Hall resistivity have shown that main charge carriers in both phases are holes whose mobility is ten times as high in the austenitic phase as in the martensitic one.

The anomalous Hall resistivity (AHE) of the Ni45.4Mn40In14.6 reaches significant magnitude of 20 microOhm*cm in the martensitic phase. Unusual scaling relation between AHE and the longitudinal resistivity is discussed.

MA 35.40 Thu 16:00 P4

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

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

The electronic and magnetic properties of CoFe and Co-based Heusler nanolayers were studied using the linear and circular magnetic dichroism in the angular distribution of photoelectrons. The layers were remanently magnetized in-situ and Co $2p_{1/2}$ and $2p_{3/2}$ core levels were probed at room temperature [2-3]. Both the polarization-dependent spectra and the dichroism indicate that the lines of the multiplet extend over the entire spectral range. In particular, the dichroism does not vanish between the two main parts of the spin-orbit doublet.

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MA 35.41 Thu 16:00 P4

Ultrafast optical Spectroscopy of $LaMnO_3/SrMnO_3$ Superlattices — •Tim Titze, Leonard Schueler, Jannik Brumm, Vitaly Bruchmann-Bamberg, Vasily Moshnyaga, Daniel Steil, and Stefan Mathias — I. Physikalisches Institut, Goettingen, Germany

We investigate photoinduced dynamics of a $LaMnO_3/SrMnO_3$ superlattice, using transient reflectivity $\Delta R/R$ at various temperatures. The superlattice exhibits a low-T_C ferromagnetic (FM) phase below $T_{C,LMO} = 200$ K with a bulk-LMO-like behavior. Further, Keunecke *et al.* reported on a high-T_C interfacial quasi-2D FM phase below $T_{C,2D} = 350$ K that results from an LMO to SMO charge transfer during sample growth [1].

By studying the system response on timescales from fs to ns we aim to determine whether the 2D interfacial phase shows a distinctly different response to an ultrafast optical stimulus than the bulk FM phase. We find that on the sub-ps timescale the T-dependent dynamics mimic the static M(T)-curve, i.e., both ferromagnetic phases seem to contribute to the ultrafast system response. On the 100 ps timescale spin-phonon coupling leads to an additional component in $\Delta R/R$ within the bulk FM phase, which is not observed for the high-T_C quasi-2D FM phase. An additional signature in the T-dependent relaxation time on a ns timescale around 300 K is tentatively attributed to the vanishing of the 2D FM phase already below its $T_{C,2D}$ due to optical excitation.

Financial support by the DFG within the CRC 1073 is acknowledged.

Ref.: [1] M. Keunecke *et al.*, doi: 10.1002/adfm.201808270

MA 35.42 Thu 16:00 P4

Frustrated triangular magnetism in new copper based single crystals. — •Aswathi Mannathanath Chakkingal[1], Chloe Fuller[2], Dmitry Chernyshov[2], Maxim Avdeev[3], Marein Christopher Rahn[1], Falk Pabst[4], Yiran Wang[4], Darren Peets[1], and Dmytro Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]ESRF, Grenoble, France — [3]ANSTO, Sydney, Australia — [4]Professur f. Anorganische Chemie II, TU Dresden, Germany

The hydrothermal technique is an efficient strategy to synthesize mineralogically inspired structures, including natural and synthetic cuprate minerals with a variety of exciting frustrated magnetic lattices. We report the hydrothermal synthesis of single crystals of a new material $Cu_4(SO_4)(OH)_6$. Single-crystal x-ray and neutron diffraction studies performed to determine the crystal structure reveal the presence of three copper layers which stack in an ABACABAC pattern in the crystal, which results in a large *b* lattice constant of 25Å. Seemingly-distorted and -expanded ${SO_4}^{2-}$ tetrahedra in the system are likely attributable to vacancies and structural disorder. The Cu^{2+} copper ions are arranged in buckled sheets consisting of ribbons of edge-sharing and corner-sharing octahedra, and form a heavily distorted triangular lattice. Diffuse scattering measured with synchrotron x-rays also reveals strong stacking-fault disorder in this system. We report details of the crystal structure and its low temperature magnetic properties.

MA 35.43 Thu 16:00 P4

High-pressure crystal growth and the magnetic phase diagram of hexagonal $GdInO_3$ — •Ning Yuan, Ahmed Elghandour, Lukas Gries, Waldemar Hergett, and Rüdiger Klingeler — Kirchhoff Institute for Physics, Heidelberg University, Germany

$GdInO_3$ is hexagonal structured system which exhibits strong geometrical frustration and improper geometric ferroelectricity [1,2]. We report the growth of macroscopic $GdInO_3$ single crystals which are used to study magnetization, specific heat, and thermal expansion in magnetic field up to 16 T. The data are used to construct the magnetic phase diagram. Anomalies in the specific heat confirm the evolution of long-range magnetic order at $T_N = 2.1$ K. At the antiferromagnetic phase boundary, anomalies in thermal expansion and magnetostriction imply significant spin-lattice coupling. A modest net magnetic moment points along the crystallographic *c* axis in the ground state. The magnetic phase diagrams for $B\|c$ and $B\|ab$ are presented for temperatures down to 400 mK and magnetic fields up to 14 T. Isothermal magnetization curves indicate a narrow 1/3 magnetization plateau as well as a sharp anomaly at about 5 T.

[1] Y. Li *et al.*, J. Mater. Chem. C 6, 7024 (2018).
[2] X. Q. Yin *et al.*, Phys. Rev. B 104, 134432 (2021).

MA 35.44 Thu 16:00 P4

Spin Excitations, Accidental Soft Modes, and Phase Diagram of the Triangular-Lattice t-t'-U Hubbard Model — •Josef Willsher[1], Hui-Ke Jin[1], and Johannes Knolle[1,2,3] — [1]TUM, Munich, Germany — [2]MCQST, Munich, Germany — [3]Imperial College London, London, UK

The structure factor is an important probe of quantum magnets but due to numerical limitations it remains a challenge to make theoretical predictions beyond linear spin wave calculations of Heisenberg-like models. In this work we study the excitation spectrum of the triangular lattice Hubbard model including next-nearest neighbour hopping within a self-consistent random phase approximation. Starting from the 120-degree and stripe magnetic orders we compute the relevant magnon spectra and discuss connections to recent experiments on triangular lattice compounds. In addition, we show that the condensation of accidental soft-modes allows us to construct the phase diagram of the model, which is consistent with previous results of the variational cluster approximation. We discuss the implications of our findings for unconventional magnon spectra and even for the presence of quantum disordered phases without long range order.

MA 35.45 Thu 16:00 P4

Exchange Enhancement of Ferromagnetic Resonance in Mn_2Au/Py — •Tobias Wagner and Olena Gomonay — Johannes Gutenberg-University Mainz, Germany

In the future, AFMs as active components will bring favourable advantages to spintronics: Robustness to external magnetic fields, temperature stability of the Néel ordered state and lack of stray fields. Therefore, AFMs are suitable for ultrafast and ultra high density spintronics. Recently, strong exchange coupling between Mn_2Au and thin layers of Permalloy ($Ni_{80}Fe_{20}$) has been shown [1]. As a consequence, the coercive field of Mn_2Au/Py was reported to be 5000 Oe, which is high compared to 200 Oe in CuMnAs/Fe [1]. High coercive fields lead to long term stability at room temperature. Due to strong exchange coupling, the AFM Néel vector and the FM magnetisation rotate coherently, when an external field is applied to the FM. Ferromagnetic resonance spectroscopy revealed two distinct frequencies for the coupled bilayer system, both of which lie above the resonance frequency of Permalloy. We model these findings using a phenomenological model. Our model enables us to demonstrate how the interfacial exchange coupling enables tuning of the ferromagnetic resonance frequency by variation of the thickness of the ferromagnetic layer.

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MA 35.46 Thu 16:00 P4

Voltage induced magneto-ionic interactions controlling magnetic properties of synthetic antiferromagnets — •Maria-Andromachi Syskaki[1,2], Takaaki Dohi[2], Jürgen Langer[1], Mathias Kläui[2], and Gerhard Jakob[2] — [1]Singulus Technologies AG, 63796 Kahl am Main, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Voltage control of magnetic properties in spintronic devices is one of the most promising device-compatible and energy-efficient ways for future storage applications [1]. This approach can be ideally realized with the advantages of a synthetic antiferromagnet (SAF) system, which provides higher thermal stability and a wide dynamic range, e.g. high domain wall velocities for nearly compensated SAFs [2] when integrated into MRAM devices. In our work, we have grown a SAF stack by magnetron sputtering consisting of two ferromagnetic layers coupled by a non-magnetic spacer layer. A thermodynamically stable skyrmion state at elevated temperatures is achievable in this stack [3]. With room temperature voltage-controlled magneto-ionic effects, we focus on the modulation of the magnetic properties in this system, i.e., the voltage control of the compensation ratio between the layers, the perpendicular magnetic anisotropy, and the antiferromagnetic RKKY coupling strength. [1] T. Nozaki et al., Micromachines 10(5), 327 (2019). [2] Y. Guan et al., Nat. Commun. 12, 5002 (2021). [3] T. Dohi, et al., Nat. Commun 10, 5153 (2019).

MA 35.47 Thu 16:00 P4

Micromagnetic simulation of magnetic reversal processes in exchange biased micro stripes — •Lukas Paetzold, Sapida Akhundzada, Christian Janzen, Michael Vogel, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Strasse 40, 34132 Kassel, Germany

Exchange bias, being first observed by Meiklejohn and Bean [1] and described as a unidirectional anisotropy, is a well-known interface effect between antiferromagnetic and ferromagnetic thin films. Initiated by field cooling [1], sputter deposition [2], or light-ion bombardment [3] the effect appears as a shift of the hysteresis loop and increased coercive fields [4]. Micromagnetic simulations [5,6] are presented for investigating the magnetic reversal processes in exchange biased micro stripes with a polycrystalline uncompensated antiferromagnetic layer. Special focus is put on the nucleation processes occurring in the microscopic range depending on the stripe width.

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MA 35.48 Thu 16:00 P4

Exchange-spring behavior at magnetic perovskite oxide interfaces — •Antonia Rieche, Martin Michael Koch, Michael Enders, Aurora Diana Rata, and Kathrin Dörr — Martin-Luther-Universität Halle-Wittenberg

Advances in ultrathin film deposition allow the investigation of exceptional properties at interfaces which significantly differ from those of bulk materials. A particular kind of interface coupling between magnets is the exchange spring, whose magnetic switching is distinctly different from that of exchange-bias coupling. To explore exchange springs in oxides, high quality $SrRuO_3/La_{0.7}Sr_{0.3}MnO_3$ (SRO/LSMO) and $La_{0.7}Sr_{0.3}CoO_3$ (LSCO/LSMO) bilayers were grown by pulsed laser deposition on different substrates with systematically varied layer thicknesses. Strong antiferromagnetic Mn-O-Ru or ferromagnetic Mn-O-Co exchange coupling connects the magnetic moments at the interface. An exchange spring resembling a Bloch wall is formed in the hard magnet due to a striking reduction of the magnetocrystalline anisotropy near the interface and return to bulk behavior further away from the interface. The thickness-dependent switching is analyzed to derive the exchange and anisotropy energies of the spring, its length and field-temperature „phase diagram“. We discuss the impact of such interfacial spin textures on magnetic switching as well as on further properties which are important for spintronics applications.

MA 35.49 Thu 16:00 P4

Effect of laser annealing on the magnetic properties of Co/Pt based multilayers — •Lokesh Rasabathina[1], Apoorva Sharma[1], Sandra Busse[3], Benny Böhm[1], Fabian Samad[1,2], Georgeta Salvan[1], Alexander Horn[3], and Olav Hellwig[1,2,4] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Laserinstitut Hochschule Mittweida, Schillerstraße 10, 09648 Mittweida, Germany — [4]Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, 09107 Chemnitz, Germany

Two modes of laser annealing, namely, Continuous Wave (CW) and Pulsed Wave (PW) mode, are used for modifying the magnetic properties of perpendicular magnetic anisotropy (PMA) multilayers in a controlled manner. For this we compare two types of samples - a PMA $(Co/Pt)_{10}$ multilayer and an antiferromagnetically interlayer exchange coupled PMA $(Co/Pt)_4/Co/Ir/(Co/Pt)_5$ multilayer. Room temperature hysteresis loops using polar MOKE magnetometry are measured for the different laser annealing modes. Thus, a relationship between the applied laser parameters and the magnetic properties is extracted, which provides an opportunity to alter magnetic properties of PMA multilayer systems locally with high spatial resolution on demand.

MA 35.50 Thu 16:00 P4

Anisotropic spin dynamics in $Mn_2Au/Ni_{80}Fe_{20}$ thin-film bilayers — •Gutenberg Kendzo[1], Hassan Al-Hamdo[1], Vitaliy Vasyuchka[1], Philipp Pirro[1], Yaryna Lytvynenko[2], Olena Gomonay[2], Mathias Kläui[2], Martin Jourdan[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany

Ferromagnets and antiferromagnets host qualitatively different spin dynamics. At the ferromagnet/antiferromagnet interface we thus expect coupled spin dynamics of hybrid character. We experimentally investigate the anisotropic coupling of spin dynamics in antiferromagnetic/ferromagnetic $(Mn_2Au/Ni_{80}Fe_{20})$ thin-film heterostructures by ferromagnetic resonance spectroscopy. To this end, we carried out measurements on two samples Mn_2Au(40nm)/$Ni_{80}Fe_{20}$(10nm; 7,5nm) as a function of the orientation of the static external magnetic field. For each orientation, the ferromagnetic resonance frequency at fixed magnetic field magnitude was measured. We find a pronounced anisotropy of the $Ni_{80}Fe_{20}$ ferromagnetic resonance. This finding is attributed to coupling of the $Ni_{80}Fe_{20}$ magnetization to the Mn_2Au Néel vector in conjunction with the Mn_2Au crystalline anisotropy.
Funding by DFG via CRC/TRR 173 "Spin+X", projects A01, A05, B12 & B13 is gratefully acknowledged.
[1] S. P. Bommanaboyena et al., Nat. Commun. 12, 6539 (2021).

MA 35.51 Thu 16:00 P4

Magnetic Anisotropies and Large Exchange Bias of Ultrathin Ni0.95Fe0.05/NiFeO Multilayers — Dimitrios Anyfantis[1], Camillo Ballani[2], Nikolaos Kanistras[2], Alexandros Barnasas[1], Georg Schmidt[2], •Evangelos Th. Papaioannou[2], and Panagiotis Poulopoulos[1] — [1]Department of Materials Science, University of Patras, 26504 Rio, Patras, Greece — [2]Institute of Physics, Martin-Luther University Halle-Wittenberg, 06120 Halle, Germany

Magnetic anisotropy at metal/oxide interfaces has played a significant role in the development of technological applications in recording, spintronics, sensors and actuators over the years[1]. In this work we present a novel method to produce high quality Ni(0.95)Fe(0.1)/NiFeO multilayers with the aid of the natural oxidization procedure and with the help of a single magnetron sputtering head [2]. Doping of Ni by only 5% Fe results in enhanced layering quality as X-ray reflectivity reveals. Due to magnetostatic anisotropy, the multilayers were found to be in-plane magnetized. Mild thermal annealing (T = 525 K) results in the enhancement of perpendicular magnetic anisotropy, mainly due to an increase in the uniaxial volume anisotropy term. Temperature-dependent hysteresis measurements between 4-400 K revealed considerable enhancement of coercivity and appearance of strong exchange bias effect.

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MA 35.52 Thu 16:00 P4

Additive Manufacturing of (Pr,Nd)-Fe-Cu-B Permanent Magnets using functionalized microparticles — •Jianing Liu[1], Lukas Schäfer[1], Holger Merschroth[2], Jana Harbig[2], Ying Yang[3], Anna Ziefuss[3], Matthias Weigold[2], Stephan Barcikowski[3], Oliver Gutfleisch[1], and Konstantin Skokov[1] — [1]Functional Materials, Technical University of Darmstadt, Germany — [2]Alarich-Weiss-Str. 16 — [3]Technical Chemistry I, University of Duisburg-Essen, Germany

Additive Manufacturing (AM) of permanent magnets is an upcoming and challenging task in material science and engineering. A microstructure with engineered grain boundaries and grain sizes necessary for high coercivity is not easily obtainable, especially when using Laser Powder Bed Fusion (L-PBF) to obtain fully dense magnets. In order to achieve the desired microstructure and hard magnetic properties after printing, we proposed Pr-Fe-Cu-B based alloy as a useful alloy system and compare this with its Nd-based counterpart. Our studies describe the Pr-Fe-Cu-B alloys and their annealing optimization for L-PBF. In order to achieve an improved flowability and refined microstructure, the grain boundary engineering with nanoparticles shows great potential. The nanoparticle functionalized Pr-Fe-Cu-B powder was being validated as a precursor for AM. During L-PBF, the hypothesis of heterogeneous nucleation induced by NP inoculums during resolidification is explored with the goal of grain refinement and realizing more uniaxial growth. We acknowledge the support of the Collaborative Research Centre/Transregio 270 HoMMage.

MA 35.53 Thu 16:00 P4

In-situ rotation of sample in the magnet with a rotator — •M. Safiri, P. Y. Portnichenko, M. Siegel, and D. S. Inosov — TU Dresden, Germany

Field-induced collective excitations in f-electron systems with multipolar order parameters were recently shown to exhibit significant anisotropy in field space even in structurally cubic systems, such as CeB6 [P. Y. Portnichenko et al., Phys. Rev. X 10, 021010 (2020)]. However, following such changes in the excitation spectrum in a neutron scattering experiment currently requires a tedious and time-consuming sample realignment for every field direction. To enable a much faster in-situ rotation of the sample inside a cryomagnet, we have designed and manufactured a compact piezo-driven rotator with a diameter of 32 mm that is compatible with cryomagnets used on the time-of-flight or triple-axis neutron spectrometers, up the maximum field of 10 T. This new piece of sample environment will allow us to change the sample orientation within 360° by rotating it precisely around the momentum transfer **Q** at low temperatures, which corresponds to a rotation of magnetic field in the vertical plane orthogonal to **Q**. This is supposed to add a new dimension to neutron-spectroscopy measurements, facilitating continuous scans vs. magnetic field angle that contain crucial information about magnetic anisotropy and other spin-orbit coupling effects.

MA 35.54 Thu 16:00 P4

MIASANS at the longitudinal neutron resonant spin echo spectrometer RESEDA — •Jonathan Leiner[1,2], Christian Franz[1,2,3], Johanna Jochum[1,2], and Christian Pfleiderer[1] — [1]Technical University of Munich, Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [3]JCNS at MLZ, FZ Jülich GmbH, Garching, Germany

The RESEDA (Resonant Spin-Echo for Diverse Applications) instrument has been optimized for neutron scattering measurements of quasielastic and inelastic processes over a wide parameter range. One spectrometer arm of RESEDA is configured for the MIEZE (Modulation of Intensity with Zero Effort) technique, where the measured signal is an oscillation in neutron intensity over time prepared by two precisely tuned radio-frequency (RF) flippers. With MIEZE, all of the spin-manipulations are performed before the beam reaches the sample, and thus the signal from sample scattering is not disrupted by any depolarizing conditions there (i.e. magnetic materials and fields). The MIEZE spectrometer is being further optimized for the requirements of small-angle neutron scattering (MIASANS), a versatile combination of the spatial and dynamical resolving power of both techniques. We present the current status of (i) newly installed superconducting solenoids as part of the RF flippers to significantly extend the dynamic range and (ii) development and installation of a new detector on a translation stage within a new larger SANS-type vacuum vessel for flexibility with angular coverage and resolution.

MA 35.55 Thu 16:00 P4

An Efficient Magnetic Hyperthermia Setup for Controlled Nanoparticle Heating — •Daniel Kuckla, Julia-Sarita Brand, Vinzenz Jüttner, and Cornelia Monzel — Heinrich-Heine-Univerity,Düsseldorf,Germany

Magnetic hyperthermia is a promising approach to enable a remote and localized heating of magnetic nanoparticles (MNPs) with various applications in condensed matter or biomedical physics. The MNPs may be positioned precisely in space and act as hot spots by increasing the temperature in the nanometer vicinity of the particle while causing minimal effects on the macroscopic environment. The heat dissipation arises from energy delivered to the nanoparticle in the form of an alternating magnetic field with ∼100kHz frequency and 50mT magnetic flux density. A particular challenge is to realize an efficient magnetic hyperthermia setup and to image the localized heating. Here, we present such setup consisting of an electromagnet in a resonance circuit and exhibiting a small form factor to be implemented under a microscope. We provide a profound characterization of the different components of this setup - the electromagnet and electric circuit, essential improvements to reduce power loss arising from electromagnetic induction as well as strategies to directly record thermal changes. We demonstrate efficient heating/cooling cycles using well-defined MNP samples in suspension and create MNP lithographically structured substrates. Our setup may be used to create localized hot spots in condensed matter samples, to create thermofunctional switches or to study heat-sensitive molecules in biophysics, among other examples.

MA 35.56 Thu 16:00 P4

Investigation of de Haas-van Alphen oscillations under temperature modulation in Bi — •Michelle Hollricher, Christian Pfleiderer, and Marc A. Wilde — Physik-Department, Technical University of Munich, D-85748 Garching, Germany

The properties of Bi have become the drosophila of studies of the electronic structure and the Fermi surface of metals [1-4]. An inherent constraint of present-day detection techniques of quantum oscillations concerns the separation of signal components associated with large differences of the effective charge carrier masses. We report the development of a detection technique for measurements of the de Haas-van Alphen (dHvA) effect by means of an inductive signal pick-up that is driven by temperature oscillations of the sample [1]. Resulting in an effective convolution of the oscillatory signal components with the derivative of the effective charge carrier mass with respect to temperature, our setup permits to discriminate elegantly light from heavy masses, and allows in-situ determination of the charge carrier effective masses. We have revisited the dHvA effect in Bi, focusing on the nature and character of the electron pockets.

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MA 35.57 Thu 16:00 P4

Visualization of Exchange Spin Coupling Constants — •Lawrence Rybakowski[1,2], Torben Steenbock[2], and Carmen Herrmann[1] — [1]Institut for Inorganic and Applied Chemistry, Luruper Chaussee 149, Hamburg, Germany — [2]Institut for Physical Chemisrtry, Luruper Chaussee 149, Hamburg, Germany

Most current methods for calculating the magnetic exchange interactions can calculate coupling constants for two and multi-spin systems, but a single number, the exchange spin coupling constant, is often poorly informative about the origins of the coupling. With our method, footing on nonrelativistic first-principle electronic structure calculations, the coupling constant can be decomposed into atomic and basis function contributions, which allows to plot a three-dimensional density distribution of the coupling constant weighted by the atomic orbital basis contributions and thus to analyze the influences of ligands and coordinations on the coupling behavior of different magnetic ions. In addition, exchange–correlation functional dependencies and influences of structure distortions on the strength and character of the exchange coupling constant can be investigated.

We can show that in complex compounds with competing exchange pathways, individual ligand classes can be associated with characteristic contributions to the total coupling constant. Furthermore, the inclusion and enhancement of exact exchange in the exchange-correlation functional induces an alternating contribution of neighboring atomic orbitals, having a direct impact on the calculated exchange coupling constants.

MA 35.58 Thu 16:00 P4

A Sacrificial Magnet System for Flux Dependent Surface Science Studies — •Danyang Liu[1], Jens Oppliger[1], Aleš Cahlík[1], Catherine Witteveen[1,2], Fabian O. von Rohr[2], and Fabian Donat Natterer[1] — [1]Department of Physics, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland — [2]Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest-Ansermet, CH-1211 Geneva, Switzerland

Here we describe the design and characterization of a NbFeB permanent magnet system that can be retrofitted to the sample holders of existing STM. Our design produces a magnetic field of up to 400 mT that is compatible with high temperature sample cleaning routines above the Curie point of the magnet frequently used in UHV experiments. We characterize the flux density using superconducting vortices in NbSe2 and BSCCO and demonstrate the life-cycle of the magnet from sample preparation to characterization. Our magnet is an accessible way to flux-dependent surface science, ranging from vortices in high-temperature superconductors to STM-enabled electron spin resonance.

MA 35.59 Thu 16:00 P4

DC-Mode Background Subtraction for the MPMS3 SQUID Magnetometer by Quantum Design — •Börge Mehlhorn[1], Anja Wolter[1], and Bernd Büchner[1,2] — [1]Leibniz IFW Dresden, D-01069 Dresden, Germany — [2]Institute for Solid State and Materials Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, D-01062 Dresden, Germany

Due to vibrating-sample SQUID magnetometry becoming more common in magnetization studies, the software satisfying the needs of slow linear DC mode became rather sparse. As one example raw-voltage background subtraction software is no longer supplied with the instruments, but is needed, whenever the background signal becomes large compared to the intrinsic magnetization signal of the sample.

As a response a handful of scientists began developing their own solutions. Most commonly known is the open source software published by M. J . Coak et al.[1] at the universities of Warwick and Cambridge free for academic use and based on *MathWorks MATLAB*.

The solution presented here is an independent work published as free (as in freedom) open source software. It is founded on the ecosystem of scientific software in the Python programming language. Therefore, it does not only allow frictionless future contributions by the scientific community, but also makes use of the countless human hours invested in that open source ecosystem in the past.

As an interesting scientific example the software will be demonstrated on a low-moment small-size 2D van-der-Waals crystal mounted on a horizontal rotator.

MA 35.60 Thu 16:00 P4

Mössbauer study of anisotropic magnetic nanoparticle systems — •Juri Kopp[1], Joachim Landers[1], Soma Salamon[1], Robert Müller[2], Sarah Essig[3], Silke Behrens[3], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Leibniz Institute of Photonic Technology — [3]Institute of Catalysis Research and Technology (IKFT), Karlsruhe Institute of Technology

Liquid crystalline (LC) systems have a wide range of applications as they combine the properties of a liquid and orientability in electric fields. In turn, if magnetic nanoparticles are added to such systems, we obtain magneto-responsive liquid crystals. Barium ferrite particles can be considered as possible candidates for use in such magneto-responsive LC systems. Accordingly, this work is geared towards the study of doped and undoped anisotropic barium ferrite nanoparticles using magnetic field and temperature dependent Mössbauer spectroscopy. In pure barium ferrite samples, the five different sublattice positions could be resolved and reorientation in magnetic fields was observed. In the doped samples an asymmetry in the Mössbauer lines as well as partial overlap of the individual sublattices' contributions was visible, which points towards altered environments of the iron atoms. In particular, the 2b site with its relatively high quadrupole level shift provides information about the magnetic orientation relative to the crystal structure. These results enable us to analyze orientation phenomena in future barium ferrite based magnetic liquid crystalline systems.

MA 35.61 Thu 16:00 P4

Fe3N nanoparticles as alternative material for magnetic fluid hyperthermia — •Yevhen Ablets, Imants Dirba, and Oliver Gutfleisch — Technical University of Darmstadt, Darmstadt, Germany

Magnetic fluid hyperthermia (MFH) is one of the modern individual and adjuvant methods for cancer treatment. Usually, iron oxide nanoparticles (IONP) are used for this purpose due to their chemical stability, non-toxicity, well-established and cost-effective production, well-known metabolism of iron in the human body. However, the heating performance of IONP is limited due to moderate values of saturation magnetization and magnetocrystalline anisotropy. Using particles with enhanced magnetic properties will enable more effective tumor treatment, and within AC magnetic field amplitude (H) and frequency (f) conditions of the so-called Brezovich-Atkinson criteria (H*f = 5x10^8 A/m*s), which leads to less discomfort for the patients.

In this work, a new synthesis method of crystalline Fe3N nanoparticles is demonstrated. Metal-organic compound iron pentacarbonyl is thermally decomposed in the presence of polyisobutylene succinimide under continuous ammonia flow. Varying gas flow concentrations and type of surfactant (oleic acid, oleylamine) Fe3O4 and Fe homogeneous spherical particles were obtained with an average diameter of 14 nm. Fe3N particles show better magnetic properties and heating performance than Fe3O4 and better chemical stability compared to Fe particles. First stage biocompatible studies are ongoing.

MA 35.62 Thu 16:00 P4

Origin of magnetic loss and noise in magnetoelastic magnetic field sensors — •Elizaveta Golubeva[1], Benjamin Spetzler[2], Franz Faupel[1], and Jeffrey McCord[1] — [1]Kiel University, Kiel, Germany — [2]Technical University Ilmenau, Ilmenau, Germany

Magnetoelastic magnetic field sensors based on the delta-E effect have proven their high potential for detecting small-amplitude and low-frequency magnetic fields. The concept of such sensors evolves from the dependency of the stiffness tensor on the applied magnetic field and can be utilized in various device configurations, including surface acoustic wave sensors and composite cantilevers. Previous research has shown that the main factor limiting the performance of such sensors comes from the sensor's intrinsic noise. However, the challenge of quantifying different noise sources has not been resolved yet. In this work, we suggest a general methodology for estimating the magnetic noise in magnetoelectric delta-E-effect sensors. Here, we present a complete physical device model and experimental analysis at the example of a millimeter-sized cantilever sensor. In this case, the magnetic noise associated with the hysteresis loss dominates the sensor performance and determines a minimal detectable field for the sensor of about 300 pT/Hz^1/2 @ 10 Hz. The described principles can also be applied to other magnetoelastic magnetic field sensors.

This work was funded by the German Research Foundation (DFG) through the Collaborative Research Centre CRC 1261 "Magnetoelectric Sensors - From Composite Materials to Biomagnetic Diagnostics" and the Carl-Zeiss Foundation via the Project MemWerk.

MA 35.63 Thu 16:00 P4

Giant and Tunneling Magnetic Resistance sensor elements based on Focused Ion Beam methods and chemical synthesis — •Laila Bondzio, Björn Büker, Nadine Fokin, Pierre Piel, and Andreas Hütten — University of Bielefeld, Germany

Common GMR and TMR sensors are based on sputter deposited multilayer stacks. Structuring these thin films using lithography can be expensive and time consuming, thus alternative ways of structuring are explored such as nanoparticle synthesis or high-precision milling via ion beam.

A dual-beam Focused Ion Beam (FIB) microscope can be used for Focused Electron Beam Induced Deposition (FEBID) to deposit small Co dots as nanoparticles, which are afterwards covered with a slightly conductive material to fill the gaps, so that a granular highly ordered, 2 dimensional GMR array is created in a bottom-up method. Alternatively, the ion beam can be used for a top-down approach by milling grid-like structures into a deposited magnetic layer to create rectangular particles. In spite of successful proof of concept measurements, higher particle densities are needed to produce a sufficiently high effect for sensor applications.

With chemical nanoparticle synthesis arrays of randomly arranged nanoparticles can be created representing the ferromagnetic layers. The organic ligand shells of e.g. oelic acid create the isolated TMR barrier between the particles. Measurements on these otherwise untreated random, 3 dimensional particle arrays have shown a broad TMR curve for high fields.

MA 35.64 Thu 16:00 P4

Two-photon lithography as a fabrication tool for 3D curved magnetic thin film arrays — •Christian Janzen[1], Sapida Akhundzada[1], Arne Vereijken[1], Michał Matczak[2], Piotr Kuświk[2], Arno Ehresmann[1], and Michael Vogel[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, DE — [2]Institute of Molecular Physics, Polish Academy of Science, ul. Mariana Smoluchowskiego 17 60-179 Poznań, PL

Fabrication of 3D magnetic nanostructures of complex geometry is a challenging task not easily achievable by standard lithography techniques. Two-photon lithography exploits the non-linear absorption properties of the utilized resist to initialize its polymerization at the volume of highest intensity, called voxel. By manipulating the three-dimensional position of the voxel, it is possible to prepare microstructures with varying Gaussian curvature (e.g., torus), being used as templates for the deposition of magnetic thin films. For preparing high-quality thin films, minimal surface roughness is required. Hence, the latter was investigated by atomic force microscopy depending on process parameters. By spatially separating the curved template from the substrate surface with an additional spacer, the magnetostatic interaction between the magnetic cap and the flat full film becomes negligible. Individual template structures are written with variable spacing to their nearest neighbors, enabling the magnetostatic interaction via strayfields as a tunable parameter of the interaction within the magnetic array.

MA 35.65 Thu 16:00 P4

Applications of 3D Nano-Lithography in Magnetism — •Jana Kredl[1], Christian Denker[1], Cornelius Fendler[2], Robin Silber[3], Hauke Heyen[1], Tristan Winkel[1], Finn-F. Stiewe[1], Nina Meyer[1], Tobias Tubandt[1], Neha Jha[1], Jakob Walowski[1], Marcel Kohlmann[1], Julia Betune[1], Chris Badenhorst[1], Alena Rong[1], Mark Doerr[1], Raghvendra Palankar[1], Mihaela Delcea[1], Uwe T. Bornscheuer[1], Robert Blick[2], Swadhin Mandal[4], Alexander Paarmann[5], and Markus Münzenberg[1] — [1]University of Greifswald, Germany — [2]Universität Hamburg, Germany — [3]VŠB-Technical University of Ostrava, Czech Republic — [4]Indian Institute of Science Education and Research Kolkata, India — [5]Fritz Haber Institute of the Max Planck Society, Berlin, Germany

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

MA 35.66 Thu 16:00 P4

Monte-Carlo study of commensurate-incommensurate phase transtion of YBaCuFeO5 — •Mukesh Sharma and Tulika Maitra — Indian Institute of Technology Roorkee, Roorkee Uttrakhand, India

Type-II multiferroic materials where ferroelectricity is driven by magnetic order are highly sought after these days. Intense research is being carried out to increase the transition temperature of multiferroicity to near room temperature. YBaCuFeO5(YBCFO) is one such rare material where it has been reported that incommensurate spiral magnetic ordering is stable upto temperatures higher than room temperature even though the presence of ferroelectricity is still debated. Motivated by the recent experimental evidence of tuning commensurate-incommensurate magnetic phase transition temperature in this system via Fe-Cu disorder, we have studied the role of anisotropic exchange and Fe-Cu site disorder on this transition. Using various exchange interactions obtained from density functional theory, our Monte-Carlo simulations show that both anisotropic exchange and site disorder play significant roles in giving rise to spiral magnetic ordering at lower temperatures.

MA 35.67 Thu 16:00 P4

Formation, effects and suppression of M-Type hexaferrite in barium titanate-spinell ferrite multiferroic composites — •Daniil Lewin, Sofia Shamsulbahrin, Vladimir V. Shvartsman, and Doru C. Lupascu — Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Germany

The combination of a ferroelectric barium titanate-based perovskite with a magnetic ferrite is a common approach for creating multiferroic composites. In some cases, however, a hexagonal phase, usually identified as barium ferrite (BaFe12O19, BaM), appears during sintering. As a noticeable difference exists in the optimal sintering temperature for both phases, it may become a challenge to create an electrically well insulating ceramic. Confronted with strong formation of BaM at high sintering temperatures (1270 °C), we investigate efficient ways to suppress its formation for combinations of barium titanate with cobalt ferrite or nickel ferrite. We show that by using a reducing atmosphere, the formation of BaM is heavily suppressed, while addition of extra cobalt oxide or nickel oxide during the synthesis can further improve the magnetoelectric coefficient while minimizing the remaining amount of BaM. A clear correlation between the amount of BaM and the polarizability and magnetoelectric coupling of the composites is established.

MA 35.68 Thu 16:00 P4

Transport properties of systematically disordered Cr_2AlC films — •Joao S. Cabaco[1], Ulrich Kentsch[1], Jurgen Lindner[1], Jurgen Fassbender[1], Christoph Leyens[2,3], Rantej Bali[1], and Richard Boucher[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholz Zentrum, Dresden-Rossendorf, Germany — [2]Institute for Materials Science, TU Dresden, Germany — [3]Fraunhofer Institute for Material and Beam Technology IWS, Dresden, Germany.

Nano-lamellar composite materials, known as MAX-phases, can possess a combination of ceramic and metallic properties. A prototype compound is Cr_2AlC, formed from a unit cell of Cr_2C sandwiched between atomic planes of Al.

In this work we study the modifications to the structural, transport and magnetic behavior of 500 nm thick Cr_2AlC after irradiation with Co^+ ions, and Ar^+ noble gas ions as control. X-ray diffraction shows that ion-irradiation induces a suppression of the 0002 reflection, indicating a deterioration of the crystal structure. Increasing the ion fluence leads to an increase of the saturation magnetization at 1.5 K, whereby both Ar^+ and Co^+ cause an increased magnetization, respectively to 150 kA.m^{-1} and 190 kA.m^{-1}, for the highest fluences used. At Co^+ fluences of 5×10^{13} ions.cm^{-2} the magnetoresistance (MR) shows a 2-order of magnitude increase, up to 3% (10 T) at 100 K. A similar effect also occurs for 5×10^{12} ions.cm^{-2} Ar^+ irradiated films, however, with a smaller MR-increase. The disordering of MAX phase films may reveal interesting spin-related transport phenomena.

MA 35.69 Thu 16:00 P4

A Floquet Green's Function technique to study ESR spectra — •Jose Reina Galvez — Center for Quantum Nanoscience, Ewha University, Seoul, Republic of Korea

This poster presents a theoretical framework to describe experiments directed to controlling single-atom spin dynamics by electrical means using a scanning tunneling microscope. The model consists of a quantum impurity connected to electrodes while an electrical time-dependent bias is applied. The quantum impurity consists of a localized electronic state, with a Coulomb repulsion U term, connected magnetically to a localized spin S.

Applying the Heisenberg picture, in the limit of weak coupling between the impurity and the electrodes, Born-Markov approximation, a quantum master equation can be obtained. The rates in this equation are derived by the non-equilibrium Green's function formalism. The Floquet theorem is used to transform the differential equation into algebraic one.

We show results in two cases. The first case is just a single atomic orbital subjected to a time-dependent electric field, and the second case consists of a single atomic orbital coupled to a second spin-1/2. This first case reproduces the main experimental features Ti atoms on MgO/Ag (100) but in a sequential tunneling regime and for different U values. The second case directly addresses the experiments on two Ti atoms.

These calculations permit us to explore the effect of different parameters to reproduce experimental fingerprints of the ESR technique.

MA 35.70 Thu 16:00 P4

Characterization of thin MgO layers grown on Fe(100) and Fe(100)-p(1x1)O — •Mira Arndt, David Janas, Giovanni Zamborlini, and Mirko Cinchetti — Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

In the field of spintronics, thin magnesium oxide (MgO) interlayers play a major role as dielectric tunneling barriers in magnetic tunnel junctions. As the most prominent example, MgO enhances the tunneling magnetoresistance of Fe/MgO/Fe heterolayers. Crucially, exposing Fe to oxygen results in rapid oxidation of the surface, which in turn highly influences the MgO growth process and makes it less reproducible, eventually, changing the device performances. This problem can be overcome by controlled passivation of the Fe surface with oxygen prior to MgO deposition. In this contribution we present the characterization of the growth of MgO layers with variable thickness on the clean Fe(100) and the passivated Fe(100)-p(1x1)O surface. The studies have been performed by employing various surface sensitive techniques, such as Auger electron spectroscopy, low energy electron diffraction

(LEED), reflective medium energy electron diffraction (MEED), and photoelectron spectroscopy (PES). Our data show that, despite evident differences in the growth behavior, the electronic properties of the two interfaces are very similar.

MA 35.71 Thu 16:00 P4

Correlation of Magnetism and Disordered Shiba bands in Fe Monolayer Islands on Nb(110) — Julia J. Goedecke[1], Lucas Schneider[1], Yingqiao Ma[3], •Khai Ton That[1], Dongfei Wang[2], Jens Wiebe[1], and Roland Wiesendanger[1] — [1]Department of Physics - University of Hamburg, Hamburg, Germany — [2]CIC Nanogune, Donostia - San Sebastian, Spain — [3]Institute of Chemistry - Chinese Academy of Sciences, Beijing, China

Two-dimensional (2D) magnet-superconductor hybrid systems are intensively studied due to their potential for realizing 2D topological superconductors with Majorana edge modes. It is theoretically predicted that this quantum state can occur in spin-orbit coupled ferromagnetic or skyrmionic 2D layers in proximity to an s-wave superconductor. However, recent examples suggest, that the requirements for topological superconductivity are complicated by the multi-orbital nature of the magnetic components and disorder effects.

Here, we investigate Fe monolayer islands grown on a surface of the s-wave superconductor with the largest gap of all elemental superconductors, Nb, with respect to magnetism and superconductivity using spin-resolved scanning tunneling spectrosopy. We find three types of Fe monolayer islands which significantly differ by their reconstruction, by the magnetism and the disordered Shiba bands, without any signs of topological gaps or edge states.

Our work illustrates, that a reconstructed growth mode of magnetic layers on superconducting surfaces is detrimental for the formation of 2D topological superconductivity.

MA 35.72 Thu 16:00 P4

Suppression of Weak Ferromagnetic Order in $SrRuO_3$ **under Pressure** — •Anh Tong[1], Pau Jorba[1], Marc Seifert[1], Stefan Kunkemöller[2], Kevin Jenni[2], Markus Braden[2], James S. Schilling[1], and Christian Pfleiderer[1] — [1]Technical University of Munich, Garching bei München, Germany — [2]University of Cologne, Cologne, Germany

In the Ruddlesden-Popper perovskite series, $Sr_{n+1}Ru_nO_{3n+1}$, intense experimental and theoretical efforts have been dedicated to unravel the nature of unconventional superconductivity in single-layer $Sr_2RuO_4 (n = 1)$ as well as a putative electronic nematic phase masking the quantum critical endpoint in the double-layer itinerant metamagnet $Sr_3Ru_2O_7$ $(n = 2)$. We report an experimental study of the zero temperature ferromagnetic-to-paramagnetic transition under pressures up to 20GPa in high quality single crystals of the infinite layer itinerant ferromagnet $SrRuO_3 (n = \infty)$. Electrical transport measurements in Bridgman anvil high pressure cells, as well as neutron depolarization measurements in diamond anvil cells were performed on $SrRuO_3$. Our study aims to investigate quantum criticality in $SrRuO_3$ and reconcile the properties of $Sr_3Ru_2O_7$ and Sr_2RuO_4 with the generic temperature-pressure-magnetic field phase diagram of itinerant ferromagnets.

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[3] G. Cao et al., Phys. Rev. B 56, 1 (1997).

MA 35.73 Thu 16:00 P4

Magneto-transport in (Bi,Sb)Te nanostructures — •Titouan Charvin[1,2], Felix Hansen[2], Silke Hampel[2], Joseph Dufouleur[2], Bernd Büchner[2,3], and Romain Giraud[1,2] — [1]Université Grenoble Alpes, CNRS, CEA, IRIG/Spintec, F-38000 Grenoble, France — [2]Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstrasse 20, D-01069 Dresden, Germany — [3]Institut für Festkörperphysik, TU Dresden, D-01062 Dresden, Germany

The investigation of Dirac fermions surface states in binary 3D topological insulators, such as Bi_2Te_3 or Sb_2Te_3, is limited by their large bulk-carrier densities. This shift of the Fermi level, away from the bulk band gap, is caused by a high density of point defects, acting as donors or acceptors. With the aim to achieve a bulk-charge compensation, we grew $(Bi_xSb_{1-x})_2Te_3$ nanostructures by chemical vapor transport, with different stoichiometries, in order to vary both the band structure and the relative contributions of different types of point defects. From magneto-transport measurements, we infer the bulk and surface carrier densities and mobilities. Although the bulk contribution to the conductivity can be reduced for some stoichiometries, all samples show a metallic-like behavior of their conductivities, with coexisting bulk and surface states contributions.

MA 35.74 Thu 16:00 P4

Electrical and thermal hall transport in compensated topological insulator $BiSbTeSe_2$ — •Rohit Sharma, Mahasweta Bagchi, Oliver Breunig, Yoichi Ando, and Thomas Lorenz — II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany

The existence of puddles in $BiSbTeSe_2$ at low temperature (T < 50K) has been detected using optical conductivity measurements, where DC electrical conductivity data shows an insulating behaviour, but above 50K, optical and transport results agree well with each other due to evaporation of charge puddles with increasing T[1]. By comparing thermal conductivity κ_{xx} and thermal hall effect κ_{xy} data with the electrical counterparts (σ_{xx} & σ_{xy}), we study a possible influence of charge puddles on thermal transport. Electrical hall conductivity (σ_{xy}) shows hole like (p-type) behaviour at elevated T, which changes to multi-band behaviour at low T. From the electrical transport data electronic contribution to thermal transport κ_e was calculated by using Wiedemann-Franz law and then compared with the measured thermal transport data where it was found that both κ_{xx} and κ_{xy} shows phonon dominated behaviour. When compared κ_{xy} and κ_e, data matches well with each other above 50K. In contrast, below 50K κ_{xy} shows a sign change and evolves to a large thermal hall signal, whereas κ_e has no sign change and smoothly decreases. Possible reason for large thermal hall effect in $BiSbTeSe_2$ will be discussed.

Funded by the DFG via CRC 1238 Projects A04 and B01

[1] N. Borgwardt et al. Phys. Rev. B. 93, 245149 (2016)

MA 35.75 Thu 16:00 P4

Topology and DC quantum transport in Floquet-driven systems — •Aya Abouelela and Johannes Kroha — University of Bonn

Recently, several works have investigated the topological properties emerging in periodically driven systems, where a periodic drive is used to engineer the band structure such as to support topologically stabilized edge modes. The topological phases of periodically driven systems have been classified across all dimensions in the periodic table of Floquet topological insulators. The Floquet multiplicity of bands implies the emergence of anomalous edge states which cross bulk gaps that do not occur in static systems. Here, we present our studies on the non-interacting topological Qi-Wu-Zhang (QWZ) model under the influence of a periodic drive, and analyze its drive-induced edge modes, using the Floquet formalism. Investigating two regimes of the driving frequency , higher or lower than the static bandwidth, the latter is shown to support anomalous edge modes. For the experimental detection of edge states, we calculate the dI/dV spectra at non-zero DC bias voltage V, using the Keldysh-Floquet formalism. We predict quantized conductance plateaus when the transport voltage is within a normal gap (V centered around $V = 0$, normal edge mode) or within an anomalous gap (V centered around $V = \pm\Omega/2$, anomalous edge mode). We also perfom a spatially resolved computation of the chiral tranmission channels of the finite- size system with finite bias applied, showing that the transport is along an edge and that it is spatially modulated corresponding to the wave number π of the (anomalous) edge mode.

MA 35.76 Thu 16:00 P4

Effects of the chiral anomaly on charge and heat transport in Weyl semimetals — •Alina Wenzel[1,2], Annika Johansson[1], and Ingrid Mertig[2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

The chiral anomaly in Weyl semimetals, which corresponds to nonconservation of chiral charge if a magnetic field is applied nonorthogonal to an electric field or a temperature gradient, leads to unconventional contributions to longitudinal charge and thermal transport, strongly depending on the external magnetic field [1-3]. We calculate the thermoelectric transport properties for Weyl systems by solving the semiclassical Boltzmann equation including a temperature gradient. To analytically calculate the transport coefficients the Sommerfeld expansion is used. The isotropic Weyl Hamiltonian [2] and an anisotropic, more realistic model to describe pairs of Weyl points [4,5] are discussed. Using the latter, Weyl semimetals with either broken time reversal or inversion symmetry are simulated and the influence of symmetry on the electric and thermal transport properties is discussed.

[1] H. B. Nielsen and M. Ninomiya, Phys. Lett. B **130**, 389 (1983)
[2] D. T. Son and B. Z. Spivak, Phys. Rev. B **88**, 104412 (2013)
[3] K. Kim, Phys. Rev. B **90**, 121108(R) (2014)
[4] S. Murakami *et al.*, Phys. Rev. B **78**, 165313 (2008)
[5] R. Okugawa *et al.*, Phys. Rev. B **89**, 235315 (2014)

MA 36: Members' Assembly

Time: Thursday 18:00–19:00 Location: H37

All members of the Magnetism Division are invited to participate.

MA 37: Skyrmions 3 (joint session MA/KFM)

Time: Friday 9:30–12:45 Location: H37

MA 37.1 Fri 9:30 H37

Emergence of zero-field non-synthetic single and catenated antiferromagnetic skyrmions in thin films — •Amal Aldarawsheh[1,2], Imara Lima Fernandes[1], Sascha Brinker[1], Moritz Sallermann[1], Muayad Abusaa[3], Stefan Blügel[1], and Samir Lounis[1,2] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [3]Department of Physics, Arab American University, Jenin, Palestine

Antiferromagnetic (AFM) skyrmions are envisioned as ideal topological magnetic bits in future information technologies. In contrast to ferromagnetic (FM) skyrmions, they are immune to the skyrmion Hall effect, might offer potential terahertz dynamics [1] while being insensitive to external magnetic. Although observed in synthetic AFM structures [2], their realization in non-synthetic AFM films has been elusive. Here[3], we unveil their presence in a row-wise AFM Cr film deposited on PdFe bilayer grown on fcc Ir(111) surface. Using first-principles, we demonstrate the emergence of single and catenated AFM skyrmions, which can coexist with the rich inhomogeneous exchange field, including that of FM skyrmions, hosted by PdFe. Besides the identification of an ideal platform of materials for intrinsic AFM skyrmions, we anticipate the uncovered solitons to be promising building blocks in AFM spintronics. -Work funded by (BMBF-01DH16027) [1] Gomonay et al., Nat. Physics 14, 213 (2018). [2] Legrand et al., Nat. Materials 19, 34 (2020). [3] Aldarawsheh et al., ArXiv:2202.12090 (2022).

MA 37.2 Fri 9:45 H37

Chiral standing spin waves in 3D skyrmion lattice — •Andrii Savchenko[1,2], Vladyslav Kuchkin[1], Filipp Rybakov[3,4], Stefan Blügel[1], and Nikolai Kiselev[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Donetsk Institute for Physics and Engineering, National Academy of Sciences of Ukraine, 03028 Kyiv, Ukraine — [3]Uppsala University, SE-75120 Uppsala, Sweden — [4]KTH Royal Institute of Technology, SE-10691 Stockholm, Sweden

The resonance excitations of the three-dimensional skyrmions lattice in the finite thickness plate of an isotropic chiral magnet were studied using spin dynamics simulations. We calculated the absorption spectra and resonance mode profile configurations for the cases of in-plane and out-of-plane excitations. These results differ from those predicted by the two-dimensional model and the model of the unconfined bulk crystal. In the case of in-plane excitation, absorption spectra dependencies on film thickness have the periodic zones with fading intensity. This effect can be explained by the formation of chiral standing spin waves, which, contrary to conventional standing spin waves, are characterized by the helical profile of dynamic magnetization of fixed chirality defined by the Dzyaloshinskii-Moriya interaction [1]. The chiral standing spin waves are localized in the inter-skyrmion area or the skyrmion core. Under out-of-plane excitation, the absorption spectrum also demonstrates the appearance of standing spin waves, which are localized in the skyrmion shell. 1. A.S. Savchenko et al, arXiv:2205.05466

MA 37.3 Fri 10:00 H37

Generalization of the collective variables approach for skyrmion strings. — •Volodymyr Kravchuk[1,2] and Markus Garst[1] — [1]Karlsruhe Institute of Technology, Germany. — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine

In a bulk saturated chiral magnet, the skyrmion core penetrates the ferromagnet volume forming a string-like object [1]. Here we describe the small-amplitude dynamics of the string, applying the generalized collective variable approach. For the collective variables, we use the coordinate- and time-dependent string position defined as the first moment of topological charge calculated for the continuously stacked horizontal cross-sections perpendicular to the applied magnetic field. The simplest "plane-wave" solution corresponds to the helix-shaped deformation of the string. In a nonlinear regime, this solution is unstable due to the Lighthill criterion, that results in a self-modulation of the wave. Using a multiscale analysis both in space and time, we show that this modulation is captured by a non-linear Schroedinger equation of focusing type. Two classes of non-linear periodic waves of skyrmion string (so-called dc- and cn-waves) are analytically predicted and numerically verified. The separatrix soliton solution just corresponds to the solitary wave found previously [1]. The developed approach is generalized for the case of arbitrary meaning of the collective variables. The latter enables us to describe the string excitations of various symmetries, e.g. breathing and elliptical modes in a nonlinear regime.

[1] V. Kravchuk, U. Rößler, J. van den Brink, M. Garst, PRB, 102, 220408(R) (2020).

MA 37.4 Fri 10:15 H37

Fermi-surface origin of helical single Q-state and skyrmion lattice in centrosymmetric Gd compounds — •Juba Bouaziz[1], Eduardo Mendive-Tapia[1], Stefan Blügel[1], and Julie Staunton[2] — [1]Forschungszentrum Jülich, Germany — [2]University of Warwick, Coventry CV4 7AL, United Kingdom

We show from first principles that cylindrical structures within the Fermi surface are the origin of the single-Q helical state in the $GdRu_2Si_2$ and Gd_2PdSi_3 intermetallic compounds. The geometry of the Fermi surface nesting describes the strength and sign of the underlying pairwise Ruderman-Kittel-Kasuya-Yosida interactions between the Gd moments as the main mechanism. These interactions are quasi-two-dimensional, isotropic within the Gd layers, and provide a transition temperature and helix period in very good agreement with experiment. Using atomistic spin-dynamical simulations, we investigate the effects of magnetic anisotropy and construct a general magnetic phase diagram that explains the stabilization of the $2Q$-skyrmion lattice observed in experiment with applied magnetic fields.

Funding: ERC Grant No. 856538 (project "3D MAGiC"), SPP 2137 "Skyrmionics" (Project No. BL 444/16), UK EPSRC Grant No. EP/M028941/1.

MA 37.5 Fri 10:30 H37

Non-Abelian Vortices in Magnets — •Filipp Rybakov[1] and Olle Eriksson[1,2] — [1]Uppsala University, Sweden — [2]Örebro University, Sweden

The non-Abelian (non-commutative) topological states in ordered media may exhibit interesting physics emerging from purely topological arguments [1].

Here we show that non-Abelian vortices also can exist in magnets [2]. We give a topological classification of these vortices and reveal their connection with Abelian topological structures, such as usual vortices, merons, skyrmions. We analyze the potential of non-Abelian magnetic vortices for memory devices and emphasize their advantage, since they provide topological protection of all information, rather than individual bits, as in Abelian cases.

[1] N. D. Mermin, Rev. Mod. Phys. 51, 591 (1979).
[2] F. N. Rybakov and O. Eriksson, arXiv:2205.15264 (2022).

MA 37.6 Fri 10:45 H37

Thermal properties of magnetic skyrmions — •Balázs Nagyfalusi[1], László Udvardi[2,3], and László Szunyogh[2,3] — [1]Wigner Research Center for Physics, Institute for Solid State Physics and Optics, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest Hungary — [3]MTA-BME Condensed Matter Research Group, Budapest, Hungary

We have recently implemented metadynamics in Monte Carlo simulation code[1], which has been modified to use the topological charge Q of magnetic skyrmions as collective variable. The free energy can thus be determined as a function of Q and its equilibrium value can be explored as a function of temperature. The knowledge of the free energy $F(Q;T)$ also permits to evaluate the chemical potential μ of the skyrmions.

We investigated the thermal evolution of magnetic skyrmions in a $Pt_{95}Ir_5$/Fe bilayer on Pd(111) and an FePd bilayer on Ir(111) substrate in the presence of a normal-to-plane external magnetic field. The equilibrium number of skyrmions and the phase boundaries are in good agreement with previous studies[2,3]. For the former system we found that Q has a maximum around 60 K and below this temperature this number drops rapidly, while for the later system it freezes in as the skyrmion lattice is a ground state of the system. The slope of $\mu(T)$ also distinguishes the different ground states of the two system.

1. Nagyfalusi *et al.*, Phys. Rev. B 100, 174429 (2019)
2. Rózsa *et al.*, Phys. Rev. B 93, 024417 (2016)
3. Schick *et al.*, Phys. Rev. B 103, 214417 (2021)

MA 37.7 Fri 11:00 H37

Constructing coarse-grained skyrmion potentials from experimental data with Iterative Boltzmann Inversion — •Jan Rothörl, Yuqing Ge, Maarten A. Brems, Nico Kerber, Raphael Gruber, Fabian Kammerbauer, Takaaki Dohi, Mathias Kläui, and Peter Virnau — Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 9, D-55099 Mainz, Germany

In an effort to understand skyrmion behavior like skyrmion lattice formation [1] or commensurability effects [2], skyrmions are often described as 2D quasi particles on a coarse-grained level evolving according to the Thiele equation. In particular, the interaction potentials are the key missing parameters for predictive modeling of experiments. We apply the Iterative Boltzmann Inversion technique commonly used in soft matter simulations to construct potentials for skyrmion-skyrmion and skyrmion-magnetic material boundary interactions from a single experimental measurement without any prior assumptions of the potential form. We find that the two interactions are purely repulsive and can be described by an exponential function for experimentally relevant micrometer-sized skyrmions. This captures the physics on experimental time and length scales that are of interest for most skyrmion applications and typically inaccessible to atomistic or micromagnetic simulations. [3]

[1] J. Zázvorka et al., Adv. Funct. Mater. 30, 2004037 (2020). [2] C. Song et al., Adv. Funct. Mater. 2010739 (2021) [3] Y. Ge et al., arXiv:2110.14333 [cond-mat.mtrl-sci] (2021)

MA 37.8 Fri 11:15 H37

Development of a current solver for studying non-linear skyrmion dynamics — •Thorben Pürling[1,2], Daniele Pinna[3], Fabian Lux[4], Jonathan Kipp[1,3], Stefan Blügel[1,3], Abigail Morrison[2,5], and Yuriy Mokrousov[3,4] — [1]Department of Physics, RWTH Aachen University, Aachen, Germany — [2]Institute of Neuroscience and Medicine 6 and Institute for Advanced Simulation 6 and JARA BRAIN Institute I, Jülich Research Centre, Jülich, Germany — [3]Peter Grünberg Institute 1 and Institute for Advanced Simulation 1, Forschungszentrum Jülich and JARA, Jülich, Germany — [4]Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany — [5]Computer Science 3 - Software Engineering, RWTH Aachen University, Aachen, Germany

Transport phenomena in skyrmionic textures have recently gained attention owing to possible applications in spintronics and in cognitive computing. While the reservoir computing aspect of skyrmions relies heavily on their nonlinear response properties, little is known about the real-space distribution of the current density that reflects the nontrivial structure of the local conductivity tensor of these complex objects. Here we report on the development of a method that provides the local current distribution for arbitrary spin textures under bias, and apply that method to study the current distribution of isolated skyrmions. We address the importance of diagonal and Hall components of the conductivity tensor for the current distribution and discuss possible relevance of our findings to reservoir computing applications.

MA 37.9 Fri 11:30 H37

Atomistic spin simulations of electric-field assisted nucleation and annihilation of magnetic skyrmions — •Moritz A. Goerzen[1], Stephan v. Malottki[1,4], Grzegorz J. Kwiatkowski[2], Pavel F. Bessarab[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany — [2]University of Iceland, Reykjavík, Iceland — [3]St. Petersburg, Russia — [4]Thayer School of Engineering, Dartmouth College, Hannover, USA

We demonstrate electric-field assisted thermally activated writing and deleting of magnetic skyrmions in ultrathin transition-metal films. We apply an atomistic spin model which is parameterised from density functional theory (DFT) calculations for a Pd/Fe bilayer on the Ir(111) surface for electric fields of $\mathcal{E} = 0, \pm 0.5$ V/Å. Based on harmonic transition-state theory [1,2], we calculate the transition rates for skyrmion nucleation and annihilation. Using these rates we quantify the probability for electric-field assisted deleting and writing of skyrmions by means of Master equations. The magnetic-field dependent skyrmion probability can be directly related to the free energy differences of the skyrmion and the ferromagnetic state and resembles a Fermi-Dirac distribution function. The obtained probability function at opposite electric fields is in striking agreement with experimental results [3].

[1] Bessarab *et al.*, Sci. Rep. **8**, 3433 (2018)
[2] von Malottki *et al.*, Phys. Rev. B **99**, 060409 (2019)
[3] Romming *et al.*, Science **341**, 636 (2013)

MA 37.10 Fri 11:45 H37

Strain and electric field control of magnetic skyrmions in Fe3GeTe2 van der Waals heterostructures — •Dongzhe Li[1], Soumyajyoti Haldar[2], and Stefan Heinze[2] — [1]CEMES, Université de Toulouse, CNRS, 29 rue Jeanne Marvig, F-31055 Toulouse, France — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstrasse 15, 24098 Kiel, Germany

Magnetic skyrmions are topologically protected chiral spin structures with particle-like properties, which are often induced by the Dzyaloshinskii-Moriya interaction (DMI). The recent discovery of truly two-dimensional (2D) magnetic materials opened up new opportunities for exploring magnetic skyrmions in atomically thin vdW materials. Here, using density functional theory and atomistic spin simulations, we predict the emergence of a large DMI in 2D vdW heterostructures where a 2D ferromagnetic metal Fe3GeTe2 monolayer is deposited on a nonmagnetic vdW layer. In particular, the DMI turns out to be highly tunable by strain and electric-field, leading to giant DMI comparable to that of ferromagnetic/heavy metal interfaces, which have been recognized as prototype multilayer systems to host skyrmion states. Our atomistic spin simulations further show that the efficient control of the DMI, the exchange coupling, and the magnetic anisotropy energy by strain, lead to the stabilization of isolated skyrmions.

MA 37.11 Fri 12:00 H37

Resonant optical Hall conductivity from skyrmions — •Sopheak Sorn[1], Luyi Yang[2], and Arun Paramekanti[3] — [1]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Department of Physics, Tsinghua University, Beijing, China — [3]Department of Physics, University of Toronto, Toronto, Canada

Metallic magnets hosting topological skyrmions exhibit the topological Hall effect, which arises from a real-space Berry-phase mechanism, and it has been used as an indirect signature of skyrmions in transport experiments. This talk will focus on the less explored impact of skyrmions on optical Hall conductivity which is studied using a two-dimensional model of conduction electrons coupled to a background skyrmion spin texture via an effective Hund's coupling. For a skyrmion crystal, a Kubo-formula calculation reveals a resonant feature in the optical Hall response at a frequency set by the Hund's coupling. A linear relation between the area under the Hall resonant curve and the skyrmion density is discovered numerically and is further elucidated in a gradient expansion analysis. The presence of the resonance is robust, persisting in a system with an isolated skyrmion and even in a three-site system hosting a trimer of noncoplanar spins, which implies the indispensable role of the local noncoplanarity. Our results suggest that the resonance can be used as a basis for a magneto-optical Kerr microscopy for visualizing skyrmions.

MA 37.12 Fri 12:15 H37

Artificial neuron based on a magnetic biskyrmion — •Ismael Ribeiro de Assis, Börge Göbel, and Ingrid Mertig — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

Skyrmionics and neuromorphics are among the most promising fields of physics with the perspective of creating future devices and technologies. Magnetic skyrmions are extremely stable and can be moved by currents which has lead to the prediction of a skyrmion-based artificial neuron [1]: When a skyrmion is pushed by current pulses, it will eventually reach a designated location and can be detected electrically. This resembles the excitation process of a neuron that fires ultimately. However, a realistic refractory process has not been achieved, so far, for such a device. The skyrmion-based neuron would keep on firing when more current pulses are applied which renders this device not useful.

In this talk we suggest that a biskyrmion solves this major issue. The attractive interaction of the two partially overlapping skyrmions and their skyrmion Hall effects lead to a unique trajectory when they are driven by current pulses: The two subskyrmion move along opposite directions to the two designated detection areas where they reverse their direction of motion until they come back and eventually reestablish the biskyrmion. During the second period the skyrmion cannot fire again. Our suggested device resembles the response of a biological neuron better than all existing skyrmion-based devices so far.

[1] S. Li et al., Nanotechnology 28, 31LT01 (2017)

MA 37.13 Fri 12:30 H37

Magnetoelastic surface states of skyrmion textures — •Lars Franke and Markus Garst — Institute for Theoretical Solid State Physics, Karlsruhe Institute for Technology, Germany

At the surface of chiral magnets uncompensated Dzyaloshinskii-Moriya interaction modifies the boundary conditions for the magnetization resulting in a so-called a surface twist. Consequently, skyrmions are expected to change their helicity from Bloch-like within the bulk of the chiral magnet to Néel-like close to the surface [1]. Resonant elastic X-ray scattering experiments [2] have confirmed this predicted change of helicity close to the surface, but the experimentally observed penetration depth was found to be an order of magnitude larger than theoretically expected. In order to account for this discrepancy, we investigate theoretically the influence of a magnetoelastic coupling on the surface twist. Analytical calculations are complicated by broken translational invariance and nontrivial boundary conditions at the surface. However, as in the uncoupled system the length scale for helicity variations is already encoded in the bulk equation. We demonstrate how to extract the length scale from a perturbative approach. The validity of these calculations is checked using micromagnetic simulations, extended with magnetoelastic coupling, of the complete surface state including boundary conditions.

[1] Three-dimensional skyrmion states in thin films of cubic helimagnets, F. N. Rybakov et al. Phys. Rev. B 87, 094424 (2013).

[2] Reciprocal space tomography of 3D skyrmion lattice order in a chiral magnet, S. Zhang et al. PNAS 201803367 (2018).

MA 38: Electron Theory of Magnetism and Correlations

Time: Friday 9:30–11:15 Location: H43

MA 38.1 Fri 9:30 H43

Magnetic torque and DMI-like spin-lattice-coupling parameters from first principles — •S. Mankovsky[1], H. Lange[1], S. Polesya[1], M. Weissenhofer[2], U. Nowak[2], and H. Ebert[1] — [1]Dept. Chemistry, LMU Munich, D-81377 Munich, Germany — [2]Fachbereich Physik, Uni. Konstanz, 78457 Konstanz, Germany

Magneto-elastic couplings can play a crucial role both for ground state magnetic properties of materials giving rise to modified forms of the magnetic ground state accompanied by a spontaneous lattice deformation, as well as for spin-lattice dynamics, e.g. having a leading role for Gilbert damping in insulators.

As the magneto-elastic properties are fully determined by the electronic structure, the corresponding spin-lattice coupling (SLC) parameters can be calculated at a first-principles level. Aiming at that, we start with the phenomenological atomistic spin-lattice Hamiltonian which can be seen as an extension of the standard Heisenberg spin Hamiltonian. Focusing on the SOC-driven SLC effects, we discuss the torque on the magnetic moment as well as the modification of the Dzyaloshinskii-Moriya interaction (DMI) induced by an atomic displacement, giving access to corresponding SLC parameters. The expressions for these SLC parameters have been worked out based on the fully-relativistic KKR Green functions formalism. Corresponding calculations have been done for different two-dimensional and three-dimensional systems. Their properties as well as possible impact on the magnetic structure are discussed in comparison with the ordinary MCA and DMI parameters.

MA 38.2 Fri 9:45 H43

Angular momentum transfer via relativistic spin-lattice coupling from first principles — •Hannah Lange[1], Sergiy Mankovsky[1], Svitlana Polesya[1], Markus Weissenhofer[2], Ulrich Nowak[2], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, Butenandtstr. 11, 81377 Munich — [2]Dept. Physics, Uni Konstanz, 78457 Konstanz

The transfer and control of angular momentum is a key aspect for spintronic applications. Only recently, it was shown that it is possible to transfer angular momentum from the spin system to the lattice on ultrashort time scales [1]. Hence, combined molecular-spin dynamics simulations using first-principles parameters might give access to the central aspects of the underlying mechanisms.

To contribute to the understanding of angular momentum transfer between spin and lattice degrees of freedom we present a scheme to calculate fully-relativistic spin-lattice coupling parameters from first-principles. By treating changes in the spin configuration and atomic positions at the same level, closed expressions for the atomic spin-lattice coupling parameters can be derived in a coherent manner up to any order. Analyzing the properties of these parameters, in particular their dependence on spin-orbit coupling, we find that even in bcc Fe the leading term for the angular momentum exchange between the spin system and the lattice is a Dzyaloshiskii-Moriya-type interaction, which is due to the symmetry breaking distortion of the lattice.

[1] Tauchert et al. Nature 602, 73 (2022).

MA 38.3 Fri 10:00 H43

Double-Exchange Enhanced Magnetic Blue-Shift of Mott Gaps — •Mohsen Hafez-Torbati[1], Davide Bossini[2], Frithjof B. Anders[1], and Goetz S. Uhrig[1] — [1]Technical University of Dortmund, Dortmund, Germany — [2]University of Konstanz, Konstanz, Germany

Strong correlations in Mott insulators induce a substantial charge excitation energy known as the Mott gap. We study how the Mott gap is affected by long-range antiferromagnetic ordering upon reducing the temperature below the Néel temperature. Our finding is that the Mott gap is increased by the magnetic ordering: a magnetic blue-shift (MBS) occurs. We unveil the origin of the MBS of the Mott gap by analyzing the Hubbard model and the Hubbard-Kondo model and clarify the subtle differences. We show that in the Hubbard model the MBS is determined by the magnetic exchange coupling. In the Hubbard-Kondo model an additional contribution proportional to the hopping is induced by the double-exchange mechanism. We describe the magnetic contribution to the band gap blue-shift observed in the optical conductivity of α-MnTe and pinpoint a hopping contribution of 64% and a magnetic exchange contribution of 36%. A MBS with the energy scale of the hopping and the exchange interaction bears the potential to enable spin-to-charge conversion on extreme time scales, highly promising for spintronic and magnonic applications.

MA 38.4 Fri 10:15 H43

A Theory for Colors of Strongly Correlated Electronic Systems — •Swagata Acharya[1], Cedric Weber[2], Dimitar Pashov[2], Mark van Schilfgaarde[3], Alexander I Lichtenstein[4], and Mikhail I Katsnelson[1] — [1]Radboud University, Nijmegen, The Netherlands — [2]King's College London, London, UK — [3]National Renewable Energy Laboratory, Colorado, US — [4]Institute of Theoretical Physics, University of Hamburg, Germany

Many strongly correlated transition metal insulators are colored, even though they have large fundamental band gaps and no quasi-particle excitations in the visible range. We pick two archetypal cases as examples: NiO with green color and MnF2 with pink color. We show that a perturbative theory based on low-order extensions of the GW approximation is able to explain the color in NiO, and indeed well describe the dielectric response over the entire frequency spectrum, while the same theory is unable to explain why MnF2 is pink. We show its color originates from higher order spin-flip transitions that modify the optical response. This phenomenon is not captured by low-order perturbation theory, but is contained in dynamical mean-field theory (DMFT), which has a dynamical spin-flip vertex that contributes to the charge susceptibility. Within our combined self-consistent GW-BSE approximation and DMFT approach we can describe the peaks in subgap charge susceptibilities in both NiO and MnF2 . As a secondary outcome of this work, we establish that the one-particle properties of paramagnetic NiO and MnF2 are both well described by an adequate single Slater-determinant theory and do not require a dynamical vertex.

MA 38.5 Fri 10:30 H43

Electron-plasmon and electron-magnon scattering in ferromagnets from first principles by combining *GW* and *GT* self-energies — Dmitrii Nabok, •Stefan Blügel, and Christoph Friedrich — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

This work combines two powerful self-energy techniques: The well-known *GW* method and a self-energy recently developed by us [1] that describes the renormalization caused by the scattering of electrons with magnons and Stoner excitations. This *GT* self-energy, which is fully **k** dependent and contains infinitely many spin-flip ladder diagrams, was shown to have a profound impact on the electronic band structure of Fe, Co, and Ni. For example, it predicted a band anomaly in iron that was later confirmed experimentally. In the present work [2], we refine the method by combining *GT* with the *GW* self-energy. The resulting *GWT* spectral functions exhibit strong lifetime effects and emergent dispersion anomalies. They are in a better agreement with experimental spectra than those obtained with *GW* or *GT* alone, even showing partial improvements over local-spin-density approximation dynamical mean-field theory. The shape of the iron band anomaly improves, too.
We acknowledge the Center of Excellence MaX Materials Science at the Exascale (EU H2020-INFRAEDI-2018) for financial support.
[1] M.C.T.D. Müller, S. Blügel, and C. Friedrich, Phys. Rev. B **100**, 045130 (2019)
[2] D. Nabok, S. Blügel, and C. Friedrich, Npj Comput. Mater. **7**, 178 (2021)

MA 38.6 Fri 10:45 H43

Effective exchange interaction in non-collinear states from electronic structure theory — •Simon Streib[1], Ramon Cardias[2], Manuel Pereiro[1], Anders Bergman[1], Erik Sjöqvist[1], Cyrille Barreteau[3], Anna Delin[2], Olle Eriksson[1,4], and Danny Thonig[4,1] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Sweden — [3]SPEC, CEA, CNRS, Université Paris-Saclay, France — [4]School of Science and Technology, Örebro University, Sweden

The determination of exchange parameters in non-collinear magnetic configurations directly from the electronic structure has been a challenge since the initial development of the Lichtenstein-Katsnelson-Antropov-Gubanov (LKAG) formalism for collinear configurations. Usually, the isotropic exchange interaction between two magnetic moments is only taken into account to bilinear order (Heisenberg exchange). We introduce instead a generalized isotropic two-spin exchange interaction, which takes all orders into account, and from which we derive an effective exchange interaction. We demonstrate how in an arbitrary non-collinear configuration this effective exchange interaction can be extracted from the energy curvature tensor, which describes the local energy curvature with respect to the directions of two magnetic moments. We apply our formalism to examples from tight-binding electronic structure and demonstrate strong fluctuations of the effective exchange interaction during spin dynamics simulations [1].
[1] S. Streib et al., arXiv:2203.11759.

MA 38.7 Fri 11:00 H43

Electric-field control of the exchange interactions — •Svitlana Polesya[1], Sergiy Mankovsky[1], Eszter Simon[1], Alberto Marmodoro[2], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, Butenandtstrasse 11, D-81377 Munich, Germany — [2]Inst. of Physics, Czech Academy of Sciences, Cukrovarnicka 10, 162 00 Praha 6, Czech Republic

The impact of an applied electric field on the exchange coupling parameters has been investigated based on first-principles electronic structure calculations by means of the KKR Green function method. The calculations have been performed for a Fe monolayer (ML) and for deposited Fe films on different substrates, i.e., metallic (Pt) and semiconducting (GaAs). We analyze the origin of the field-induced change of the exchange interactions J_{ij} and the features of their field-dependent behavior specific for the studied systems. In particular, rather pronounced changes of J_{ij} have been found for the Fe/Pt(111) system due to the localized electronic states at the Fe/Pt interface. In the case of Fe/GaAs(001) films we discuss also the dependence of the field-induced modification of J_{ij} on the thickness of the Fe film. For all studied systems, a strong impact of surface relaxation is found both for the ground-state exchange parameters as well as for their field induced modification.

MA 39: Magnetic Particles / Clusters

Time: Friday 9:30–11:00 Location: H47

MA 39.1 Fri 9:30 H47

Direct determination of magnetic properties from energy lansdscapes around trapped magnetic beads — Florian Ostermaier, Moritz Quincke, Benjamin Riedmüller, Meng Li, Manuel Herschel, and •Ulrich Herr — Institut für Funktionelle Nanosyteme, Universität Ulm

Many Lab-on-Chip applications make use of micrometer sized polystyrene beads containing superparamagnetic iron oxide nanoparticles. Precise knowledge of magnetic properties is important for well-controlled manipulation by magnetic fields. We present a study of pairs of magnetic beads trapped in a current-carrying micro ring structure combined with a superimposed homogeneous field [1]. The trapped particles interact via repulsive dipole-dipole interaction. From analysis of the Brownian motion of the trapped particles we can extract information about the trap stiffness as well as the magnetic moments of the beads. The trap stiffness obtained in this way is compared to analytical and numerical calculations of the magnetic field distribution in the vicinity of the micro ring structure. We find that the restricted movement of the two interacting beads in the trap structure leads to a faster and more accurate measurement of the beads compared to observations made on single beads trapped in the same structure.
[1] F. Ostermaier, M. Quincke, B. Riedmüller, M. Li, M. Herschel, U. Herr, J. Phys. Chem. C 2022, 126, 7272-7280, DOI 10.1021/acs.jpcc.2c00759

MA 39.2 Fri 9:45 H47

Room-temperature synthesis of AuFe solid solution nanoparticles and their transformation to Au/Fe Janus nanostructures — Maria V. Efremova[1], Marina Spasova[2], Markus Heidelmann[3], Michael Farle[2], and •Ulf Wiedwald[2] — [1]Department of Applied Physics, Eindhoven University of Technology, Netherlands — [2]Faculty of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Germany — [3]ICAN - Interdisciplinary Center for Analytics on the Nanoscale and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Germany

AuFe solid solution nanoparticles (NPs) are synthesized in ambient conditions by colloidal chemistry previously established for a Fe_3O_4 – Au core-shell morphology [1]. These AuFe NPs preserve the fcc structure of Au with paramagnetic Fe ions incorporated. Interestingly, the solid solution is metastable at room temperature forming Fe-rich regions in the Au matrix during storage. In situ annealing experiments up to 700°C in a transmission electron microscope and vibrating sample magnetometer leads to segregation of metallic Fe from the AuFe solid solution finally forming Au/Fe Janus NPs. The ferromagnetic bcc Fe grows epitaxially on low index fcc Au planes. The study facilitates the reassessment of possible applications of such NPs leading to a new material for magnetoplasmonics. First tests for biomedical applications are presented.

[1] M.V. Efremova, M. Spasova, M. Heidelmann, et al., Nanoscale 13, 10402 (2021).

MA 39.3 Fri 10:00 H47

Structural, chemical and magnetic properties of iron-oxide core-shell nanocubes — •Aladin Ullrich, Michael Kühn, and Manfred Albrecht — Institut für Physik, Universität Augsburg, 86159 Augsburg, Germany

Iron oxide nanoparticles in the size range from 8 to 17 nm were synthesized by thermal decomposition of iron oleate precursor in a high-boiling solvent with Na-oleate as surfactant to produce cubic nanoparticles. The structural composition of the nanoparticles was investigated by transmission electron microscopy and electron energy loss spectroscopy, revealing a core-shell structure with a wustite like structure in the core and a spinel like structure in the shell [1]. Changes in the oxidation state of the iron as well as the core/shell ratio were determined. The core/shell ratio was tuned by successive oxidation until the core had disappeared completely. A sample series consisting of 8 different core/shell ratios was produced during the oxidation process. The magnetic properties of this antiferromagnetic core - ferrimagnetic shell system like exchange bias, coercivity, and blocking behaviour were investigated. With decreasing core/shell ratio the blocking temperature, the coercivity, as well as the exchange anisotropy decreased. Besides this, the influence of the particle size on the magnetic properties was studied as well. Here, for rising particle size an increasing blocking temperature, as well as an increasing exchange anisotropy in the blocked state at low temperatures was found.

[1] A. Ullrich, et al., Sci. Rep. 9, 19264 (2019).

MA 39.4 Fri 10:15 H47

Effect of laser treatment on catalyst materials investigated by Mössbauer spectroscopy — •Soma Salamon[1], Joachim Landers[1], Swen Zerebecki[2], Sven Reichenberger[2], Stephan Barcikowski[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Institute for Technical Chemistry I and CENIDE, University of Duisburg-Essen

Mössbauer spectroscopy is utilized as a non-destructive, element-specific measurement method to probe hyperfine interactions in spinels that are promising candidates for application in electrocatalysis. By recording low temperature (4.3 K) high field (5-10 T) spectra, it is possible to discern individual contributions from tetrahedrally and octahedrally coordinated crystallographic sites found in the spinel lattice of materials such as $CoFe_2O_4$, enabling access to the degree of inversion. Latter provides the distribution of Fe ions across these sites, while also allowing insight regarding the displacement of other ions within the lattice. This enables us to correlate changes in ion distribution in the lattice with improvements in catalytic activity, also giving clues about which ions on which positions serve as active sites during catalysis. Our results show that single-pulse laser excitation can selectively modify the ion distribution, while leaving the particles and their morphology largely intact. Further experiments also include tests of laser-induced diffusion of Fe into Co_3O_4 particles, with the use of isotope-pure ^{57}Fe allowing Mössbauer experiments to be performed on samples that do not normally contain any Fe. Funding by the DFG via the CRC/TRR 247 (ID 388390466, Projects B2, C5) is acknowledged.

MA 39.5 Fri 10:30 H47

Towards FeRh nanoparticles for printable magnetocaloric media — •Joachim Landers[1], Soma Salamon[1], Ruksan Nadarajah[2], Shabbir Tahir[2], Benedikt Eggert[1], Bilal Gökce[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Materials Science and Additive Manufacturing, University of Wuppertal

Magnetocaloric (MC) materials are promising candidates for energy efficient cooling applications. Here, FeRh nanoparticles prepared via laser ablation in liquids (LAL) are studied as possible means towards printable MC media. First experiments focused on how to minimize surface oxidation during nanoparticle preparation in solution. After ensuring low oxidation levels, our main interest was to find a method to regain the FeRh B2 structure and its MC properties during further processing. For that purpose, extensive studies via magnetometry, XRD and Mössbauer spectroscopy were performed to analyze magnetic structure and phase composition when exposing the particles to elevated temperatures, as would occur during laser printing of MC structures. We observed a transition from the predominant γ-FeRh-phase formed during laser particle synthesis to the B2-phase we aimed for, constituting a maximum B2-fraction of ca. 90 % of the material. Ongoing studies are currently searching for optimum processing parameters for laser-sintering of the FeRh-NP-based inks in an approach to form 2D magnetocaloric structures, with first results indicating the presence of the field-induced B2-phase antiferro- to ferromagnetic transition. This work is supported by the DFG through CRC/TRR 270.

MA 39.6 Fri 10:45 H47

Drifting inwards in protoplanetary discs: The role of hydrogen on planetesimal formation — •Cynthia Pillich[1], Janosch Tasto[1], Tabea Bogdan[2], Joachim Landers[1], Gerhard Wurm[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany — [2]Faculty of Physics, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Dust particles in protoplanetary discs, which can be seen as building blocks for planetesimals, are coupled to gas, mostly hydrogen. Due to this coupling, those particles may drift towards the inner part of the disc and are therefore exposed to very high temperatures, allowing for compositional and structural changes.

To simulate the conditions at the early phase of planetary formation, two chondrites were milled to dust and subjected to temperatures up to 1400 K in a hydrogen atmosphere of approximately 1 mbar. The changes in composition were then studied by the means of ^{57}Fe Mössbauer spectroscopy and magnetometry.

Comparing these results to vacuum tempered dust, we observe an influence of the heating atmosphere on compositional changes in the meteorites. At very high temperatures (>1200 K), Fe silicates are mostly reduced to metallic FeNi, altering adhesive properties of protoplanetary dust and therefore the potential for planetesimal growth.

Funding by the DFG (projects WE 2623/19-1 and WU 321/18-1) is gratefully acknowledged.

MA 40: Weyl Semimetals

Time: Friday 9:30–10:45 Location: H48

MA 40.1 Fri 9:30 H48

Magneto-optical detection of topological contributions to the anomalous Hall effect — •Felix Schilberth[1,2], Nico Unglert[3], Lilian Prodan[1], Christine Kuntscher[4], Liviu Chioncel[3], and Sándor Bordács[2] — [1]Experimentalphysik V, Augsburg University, Augsburg, Germany — [2]Department of Physics, BME Budapest, Hungary — [3]Theoretische Physik III, Augsburg University, Augsburg, Germany — [4]Experimentalphysik II, Augsburg University, Augsburg, Germany

The anomalous Hall effect (AHE) is a profound manifestation of non-trivial band structure topology in magnetic materials. The ambiguous separation of its intrinsic and extrinsic contributions leads to a fundamental limitation in identifying topological states based on common magnetotransport experiments. Here we demonstrate, via a case study on the prominent topological kagome magnet Fe_3Sn_2, that the intrinsic contribution to AHE can be determined unambiguously from the broadband spectrum of the optical Hall effect, obtained by energy-resolved magneto-optical Kerr-effect (MOKE) measurements. Using MOKE spectroscopy complemented with material-specific theory, we identified the interband excitations responsible for the intrinsic AHE. We found that low-energy transitions, tracing "helical volumes" in momentum space reminiscent of the formerly predicted helical nodal lines, substantially contribute to the AHE, which is further increased by contributions from multiple higher-energy interband transitions. Our calculation also shows that local Coulomb interactions lead to important band reconstructions near the Fermi level.

MA 40.2 Fri 9:45 H48

Magnetic and transport properties of Mn_3Sn and Fe doped Mn_3Sn Weyl semimetal — •SUBHADIP JANA — Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institute (PGI-4), JARA-FIT, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

A large Anomalous Hall Effect (AHE) has been found in Mn_3Sn due to the non-vanishing Berry flux emerging from the Weyl points. This compound draws enormous interest due to the complicated magnetic structure and its correlation with the transport properties. We observed AHE from 420 K (T_N = 420 K) down to 5 K for $Mn_{3.17}Sn$. From single-crystal neutron diffraction, we conclude that the magnetic structure is commensurate with magnetic moments in the hexagonal basal plane between 420 K (T_N) < T < 5 K. An additional incommensurate phase appears below 250 K. The presence of AHE in the whole temperature range is consistent with the commensurate magnetic structure. Fe doping influences the nearest-neighbor exchange energy, thereby changing the magnetic and transport properties. The Néel temperature was found to be 405 K for $Mn_{3.02}Fe_{0.08}Sn$, slightly lower than the parent compound. The commensurate magnetic structure has been observed between 210 K < T < 405 K from neutron powder diffraction. An incommensurate magnetic phase was observed below 210 K. The electro-transport study of Fe-doped sample shows vanishing AHE below 207 K. Therefore, we conclude that Fe doping significantly influences the magnetic structure in the commensurate region and that AHE completely vanishes in the incommensurate region.

MA 40.3 Fri 10:00 H48

Anomalous transport properties of the topological (Weyl) semimetal: Hexagonal - $(Mn_{1-\alpha}Fe_\alpha)_3Ge$ — •VENUS RAI[1], SHIBABRATA NANDI[1], ANNE STUNAULT[2], WOLFGANG SCHMIDT[3], SUBHADIP JANA[1], JIAN-RUI SOH[4], JÖRG PERSSON[1], and THOMAS BRÜCKEL[1] — [1]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institute (PGI-4), JARA-FIT, Forschungszentrum Jülich, Germany — [2]Institut Laue-Langevin, 71 avenue des Martyrs, CS20156, Grenoble, France — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at ILL, 71 Avenue des Martyrs, Grenoble, France — [4]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

Weyl semimetal (WS) - Mn_3Ge displays a large anomalous Hall effect (AHE), which originates from the non-zero Berry curvature. The location and separation of the Weyl nodes can be tuned using a suitable dopant. So, we have studied the evolution of transport properties of single-crystal $(Mn_{1-\alpha}Fe_\alpha)_3Ge$. We observed that the strength of AHE and chiral anomaly weakens drastically with an increase in Fe doping and vanishes beyond $\alpha = 0.22$. Polarized and unpolarized neutron diffraction of $\alpha = 0.22$ showed that the magnetic structure of the compound remains the same as that of the parent compound, only in the temperature regime where AHE and the chiral anomaly are observed. These observations suggest the location of Weyl points and separation between a pair of Weyl points change significantly with Fe doping. Therefore, suitable dopants can be used to tune the transport properties of the WS.

MA 40.4 Fri 10:15 H48

Prediction of a new type-I Weyl semimetal in a full-Heusler compound — •DAVIDE GRASSANO and NICOLA MARZARI — Theory and Simulations of Materials (THEOS) and National Center for Computational Design and Discovery of Novel Materials (MARVEL), Ecole Polytechnique Federale de Lausanne, CH-1015 Lausanne, Switzerland

Weyl semimetals are a class of topological semimetals with linear band crossings close to the Fermi level with non-trivial chirality, the existence of which gives rise to several exotic physical properties[1,2]. In order for such crossings to exist, either time-reversal or inversion symmetry must be broken[3]. Here we identify a new inversion-breaking Weyl semimetal. This material shows several features that are comparatively more intriguing with respect to other known inversion-breaking Weyl semimetals. The distance between two neighboring nodes is large enough to observe a wide range of linear dispersion in the band and only one kind of nodes can be identified. Finally, the lack of other trivial points insures that the low-energy properties of the material can be directly related to the presence of the Weyl nodes.

[1] Murakami S., New Journal of Physics 9.9 (2007):356
[2] Armitage NP, Mele EJ, Vishwanath A. - Rev. Mod. Phys. 90.1 (2018):015001
[3] Wan, Xiangang, et al. Phys. Rev. B 83.20 (2011): 205101

MA 40.5 Fri 10:30 H48

Multifold Hopf semimetals — •ANSGAR GRAF and FRÉDÉRIC PIÉCHON — Université Paris-Saclay, CNRS, Laboratoire de Physique des Solides, 91405, Orsay, France

Three-dimensional (3D) topological semimetals exhibit linear energy band crossings that act as monopole sources of Berry curvature. Here, we introduce *multifold Hopf semimetals (MHSs)*, which feature linear N-fold crossing points each of which acts as a *Berry dipole*. We construct models with $N = 3, 4, 5$ bands and show that their physical properties are crucially affected by the Berry dipole: First, it makes the Landau level spectrum strongly dependent on the orientation of an external magnetic field. Second, it causes an anomalous Hall effect and weak field magnetoconductivities resembling the chiral anomaly, chiral magnetic and magnetochiral effects familiar from a pair of coupled Weyl nodes. Gapping out MHSs, we obtain multiband Hopf insulators (MHIs) with Hopf numbers up to $\mathcal{N}_{\mathrm{Hopf}} = 10$. MHSs and MHIs provide a fertile playground to explore delicate topology and exhibit analogies to 2D Dirac semimetals and Chern insulators.

MA 41: Micro- and Nanostructured Magnetic Materials

Time: Friday 11:30–12:45 Location: H47

MA 41.1 Fri 11:30 H47

Dynamic properties of magnetic Nanoparticles: arrangement-, distance- & frequency-dependent properties — •NILS NEUGEBAUER[1,2], HELMUT SCHULTHEISS[3], XINGCHEN YE[4], and PETER KLAR[1,2] — [1]Institute of Experimental Physics I, 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]Helmholtz-Center Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [4]Department of Chemistry, Indiana University, Bloomington, 47405 Indiana, United States

Investigations focusing on the mutual dipolar interactions of magnetic nanoparticles (MNPs) are presented. As nanoparticles may be arranged into highly ordered, crystal-like structures, so called mesocrystals, novel properties may arise due to the introduction of an additional degree of freedom in manipulating the magnetic properties of a material. Manipulating the interparticle distance, distinct spectral features related to the dipole-dipole interaction can be observed. Based on these nano-building blocks, assemblies of MNPs of well-defined size and shape can be constructed. Such assemblies show distinct collective properties, e.g. well-localized magnetic vibrational modes, frequency- and field-dependent characteristics. The experiments are supported by utilizing numerical simulations of corresponding model systems to underline the observed characteristics.

MA 41.2 Fri 11:45 H47

Quantitative analysis of magnetic states in an artificial spin ice by off-axis electron holography — •TERESA WESSELS[1,2], SEBASTIAN GLIGA[3], SIMONE FINIZO[3], ANDRAS KOVACS[2], and RAFAL DUNIN-BORKOWSKI[2] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University Duisburg-Essen, 47057 Duisburg, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [3]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

The study of emergent phenomena in artificial spin ices (ASIs) consisting of patterned nanomagnets is presently the focus of intense research. We used off-axis electron holography in the transmission electron microscope to quantitatively measure the magnetic phase shift induced by ASI with chiral geometry. The phase shift of the electron wave was measured using an electron biprism and interpreted using a model-based iterative reconstruction algorithm to retrieve the projected in-plane magnetization. The permalloy nanomagnets were patterned on a SiN membrane using lift-off lithography. Magnetic interactions within individual arrays were studied by applying in-plane magnetic fields to the sample. The reconstructed magnetization shows a single-domain state of the nanomagnets with an average magnetic polarization of 0.73 T. The low magnetic polarization value may result from a combination of the microstructure, composition, and oxidation. The project received funding from the ERC (856538) and the DFG (392476493, 405553726).

MA 41.3 Fri 12:00 H47

Monolayer MnX and Janus XMnY (X, Y= S, Se, Te): A New Family of 2D Antiferromagnetic Semiconductors — •Shahid Sattar, Md Fhokrul Islam, and Carlo Maria Canali — Department of Physics and Electrical Engineering, Linnaeus University, Kalmar SE-39231, Sweden

We present first-principles results on the structural, electronic, and magnetic properties of a new family of two-dimensional antiferromagnetic (AFM) manganese chalcogenides, namely monolayer MnX and Janus XMnY (X, Y= S, Se, Te). By carrying out calculations of the phonon dispersion and ab-initio molecular dynamics simulations, we first confirmed that these systems, characterized by an unconventional strongly-coupled-bilayer atomic structure (consisting of Mn atoms buckled to chalcogens forming top and bottom ferromagnetic (FM) planes with antiparallel spin orientation) are dynamically and thermally stable. The analysis of the magnetic properties shows that these materials have robust AFM order, whereas electronic structure calculations reveal that pristine MnX and their Janus counterparts are indirect-gap semiconductors, covering a wide energy range and displaying tunable band gaps by the application of biaxial tensile and compressive strain. Interestingly, owing to the absence of inversion and time-reversal symmetry, and the presence of an asymmetrical potential in the out-of-plane direction, Janus XMnY become spin-split gapped systems, presenting a rich physics yet to be explored. Our findings provide novel insights in this physics, and highlight the potential of two-dimensional manganese chalcogenides in AFM spintronics.

MA 41.4 Fri 12:15 H47

Magnetic properties of cobalt - nanomagnets: towards spin qubit control — •Liza Zaper[1,2], Peter Rickhaus[2], Alexander Stark[2], Floris Braakman[1], and Martino Poggio[1] — [1]University of Basel, Basel, Switzerland — [2]Qnami AG, Muttenz, Switzerland

A promising platform to realise quantum computation uses the spin states of confined electrons to define the qubit. In order to achieve reliable control and high integration of spin qubit devices on a chip, we aim to pattern nanometer-scale magnets that have large magnetic field gradients at the position of the confined electron. We fabricate highly magnetic cobalt nanostructures using focused-electron-beam-induced deposition. We characterize the magnetization properties of the nanomagnets by NV scanning microscopy, as well as magnetotransport. The scanning probe images indicate the structure of the magnetic domains and the profile of the magnetic stray fields, which can be further used as a guideline for qubit device optimisation.

MA 41.5 Fri 12:30 H47

Cellulose nanocomposite with $SrFe_{12}O_{19}$ nanoparticles as a novel magnetic nanopaper coating — •Andrei Chumakov[1], Korneliya Gordeyeva[2], Calvin J. Brett[1,2], Anastasia V. Riazanova[2], Dirk Menzel[3], Daniel Soederberg[2], and Stephan V. Roth[1,2] — [1]DESY, Hamburg, Germany — [2]KTH Royal Institute of Technology, Stockholm, Sweden — [3]TU Braunschweig, Braunschweig, Germany

The possibility of the coating by a new magnetic nanocomposite based on negatively charged cellulose colloids (1360 μmol/g) and positively charged hard magnetic hexaferrite ($SrFe_{12}O_{19}$) nanoparticles with a large permanent magnetic moment was demonstrated. Thin nanofilms of magnetic cellulose composite were obtained by spray deposition on a silicon substrate and studied by microscopic imaging, surface-sensitive X-ray scattering, and magnetic determining techniques. Ferromagnetic nanoparticles are uniformly distributed in the cellulose matrix and form a nanocomposite due to the opposite charges of the initial components. Magnetic nanoplates show a predominant orientation parallel to the plane of the substrate and the resulting nanocomposite has the highest intrinsic coercivity field inherent in the properties of individual nanoparticles. Coatings of magnetic nanopaper with a large coercive field can be widely used from catalysis to promising nanoelectronic devices.

MA 42: Magnetic Heuslers

Time: Friday 11:30–12:45 Location: H48

MA 42.1 Fri 11:30 H48

First-principles study of magnetic tunnel junctions based on half-metallic and spin-gapless semiconducting Heusler compounds: Reconfigurable diode and inverse TMR effect — •Thorsten Aull, Ersoy Sasioglu, and Ingrid Mertig — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, 06120 Halle (Saale)

Magnetic tunnel junctions (MTJs) based on half-metallic magnets (HMMs) and spin-gapless semiconductors (SGSs) exhibit unique properties, such as current rectification, i.e., diode effect, and reconfigurability in addition to a tunnel magnetoresistance (TMR) effect [1]. We investigate from first-principles MTJs based on SGS and HMM quaternary Heusler compounds [2]. Our quantum transport calculations have demonstrated that these MTJs exhibit current rectification with high on/off ratios. Moreover, depending on the relative orientation of the magnetization of the electrodes, the MTJ allows the electrical current to pass either in one or the other direction, which leads to an inverse TMR effect. We show that, in contrast to conventional semiconductor diodes, the rectification bias voltage window of the MTJs is limited by the spin gap of the HMM and SGS Heusler compounds. The combination of nonvolatility, reconfigurable diode functionality, and high Curie temperatures of the electrode materials makes the proposed MTJs very promising for room temperature spintronic applications and opens new ways to magnetic memory and logic concepts.

[1] N. Maji and T. Nath, Appl. Phys. Lett. **120**, 072401 (2022).
[2] T. Aull *et al.*, arXiv:2202.06752 (2022).

MA 42.2 Fri 11:45 H48

Exploring all 3d-metal Heusler alloys for functional properties: density functional theory + Monte Carlo study — •Madhura Marathe and Heike C. Herper — Department of Physics and Astronomy, Uppsala University, 75120 Uppsala, Sweden.

The search for cost-effective and rare-earth metal free permanent magnets is essential for various applications. In this study, we explore a novel class of Heusler alloys consisting of all 3d-metals. We do high-throughput studies using an electronic structure database to search for X_2YZ-type Heuslers (X = Fe, Ni) with tetragonal symmetry and high magnetic moments. We perform density functional theory calculations to obtain the ground state structure, magnetic anisotropy energy (MAE) as well as the exchange interaction parameters J_{ij} for selected materials. Using the calculated J_{ij}'s, we map our system on a Heisenberg model and perform Monte Carlo simulations to calculate the Curie temperature. Through such multiscale modeling, we aim to identify potential candidates for permanent magnets. We find that for these systems J_{ij}'s have oscillations over a long range with both ferromagnetic and antiferromagnetic interactions, and it is essential to include these in the model to capture correct transition.

MA 42.3 Fri 12:00 H48

High-throughput calculations on Co-based Heusler alloys assisted with the measurement of phase diagram in the related ternary system — •Kun Hu — Technical University Darmstadt Otto-Berndt-Straße 3, 64287 Darmstadt

Abstract: High-throughput (HTP) density functional theory (DFT) calculations have been carried out on Co-based Heusler alloys, combined with Exact Muffin-Tin Orbitals (EMTO) methods and Uppsala Atomistic Spin Dynamics (UppASD) package. Firstly, the stability of the Co2XY and X2CoY phases have been calculated and selected as parent phases which mainly center on the crystal structure and the tetragonal distortion considering formation energy and distance to the convex hull. And then, the specific properties of curie temperature (Tc) and magneto-crystalline anisotropy energy (MAE) of these phases have been calculated, of which some typical compounds show a high Tc and large MAE. Furthermore, the phase diagram of Co-Pt-Ti, Co-Ge-Ti, Co-Ge-Zr, and Co-Ge-Hf ternary systems were measured through a technique of alloy sampling and diffusion triple. Based on the results from Electron Probe Microanalysis (EPMA) and X-ray diffraction (XRD) techniques, the isothermal sections of these systems were constructed at different temperatures. Several ternary phases were detected and the relevant composition range was confirmed. The current study found interesting results that the Heusler phase Co2TiGe showed a remarkable composition range.

MA 42.4 Fri 12:15 H48

Tuning of the effective magnetic decoupling in Ni-Mn-(In,Sn) Heusler alloys — •Olga N. Miroshkina[1], Francesco Cugini[2,3], Simone Chicco[2], Fabio Orlandi[4], Giuseppe Allodi[2], Pietro Bonfà[2], Vincenzo Vezzoni[2], Lara Righi[2,3], Franca Albertini[3], Roberto De Renzi[2], Massimo Solzi[2,3], and Markus E. Gruner[1] — [1]Department of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]University of Parma, Parma, Italy — [3]IMEM-CNR, Parma, Italy — [4]Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, United Kingdom

The magnetocaloric effect at first-order phase transitions is considered as an efficient and ecologically friendly alternative to conventional compressor cooling. This contribution is devoted to the complex magnetic ordering mechanisms in magnetocaloric Ni-Mn-(In,Sn) Heusler alloys, which we explore by means of density functional theory. The calculations accompany extensive experimental investigations, which reveal a non-monotonic trend in the Curie temperature and an effective magnetic decoupling of 4a and 4b sublattices [1]. Our first-principles calculations confirm a composition-dependent competition of the effective ferromagnetic and antiferromagnetic coupling between the sublattices, which can be directly controlled by electron doping in terms of In/Sn substitution. This result shows the possibility of fine-tuning of Heusler materials via exchanging the main-group element increasing the range of their potential applications. This work is funded by DFG within CRC/TRR 270 (project no. 405553726).

[1] F. Cugini et al., Phys. Rev. B 105, 174434 (2022).

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Noncollinear magnetic order in epitaxial thin films of the MnPtGa hard magnet — •Rebeca Ibarra[1,2], Edouard Lesne[1], Bachir Ouladdiaf[3], Ketty Beauvois[3], Alexandr Sukhanov[2], Rafal Wawrzyńczak[1], Walter Schnelle[1], Anton Devishvili[3], Dmytro Inosov[2], Claudia Felser[1], and Anastasios Markou[1] — [1]Max-Planck-Institute für Chemische Physik fester Stoffe, D-01187 Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, D-01069 Dresden, Germany — [3]Institut Laue-Langevin, CS20156, 38042 Grenoble Cedex 9, France

Noncollinear magnetism has attracted great attention in the recent years and promise rich exotic properties with potential for spintronic applications. In this work, we present a detailed analysis of the structural and magnetic properties of high-quality thin films of the hexagonal MnPtGa hard magnet grown on $Al_2O_3(0001)$ substrates. The films crystalize in the $P6_3/mmc$ space group, with an ordering temperature of $T_C = 263$ K into a ferromagnetic (FM) state, followed by a spin reorientation transition at $T_{sr} \sim 160$ K. A large uniaxial magnetic anisotropy is observed in this centrosymmetric compound. We further investigate the magnetic transitions by single-crystal neutron diffraction at zero applied magnetic field. The emergence of the structurally forbidden (001) Bragg reflection for $T < 160$ K, unequivocally determines a transition to a spin canted state, where the Mn magnetic moments align ferromagnetically along the c-axis and antiferromagnetically in the basal plane, resulting in a spin canting angle of 20° respect to the c-axis.