Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

(Lecture halls HSZ 02, HSZ 04, HSZ 401, HSZ 403, and POT 6; Poster P1 and P2/EG)

Invited Talks

MA 1.1	Sun	16:00–16:30	HSZ 04	**Making better batteries? – From Li-ion to Na-ion batteries** — •Philipp Adelhelm
MA 1.2	Sun	16:30–17:00	HSZ 04	**Sustainable Thermoelectric Materials Predicted by Data Mining and Machine Learning** — •Kornelius Nielsch
MA 1.3	Sun	17:00–17:30	HSZ 04	**Design strategies for electrocatalysts – an electrochemist's perspective** — •Kristina Tschulik
MA 1.4	Sun	17:30–18:00	HSZ 04	**Green magnetic materials for efficient energy, transport and cooling applications** — •Oliver Gutfleisch
MA 2.1	Mon	9:30–10:00	HSZ 02	**Two-dimensional Skyrmions in the real three-dimensional world** — •Nikolai Kiselev
MA 8.1	Mon	15:00–15:30	HSZ 04	**Optical control of antiferromagnetism** — •Christian Tzschaschel
MA 14.1	Tue	9:30–10:00	HSZ 04	**Antiferromagnetism-driven two-dimensional topological nodal-point superconductivity** — •Roberto Lo Conte, Maciej Bazarnik, Eric Mascot, Krisztián Palotás, Levente Rózsa, László Szunyogh, André Kubetzka, Dirk K. Morr, Kirsten von Bergmann, Roland Wiesendanger
MA 25.1	Wed	9:30–10:00	HSZ 04	**MAGNOTHERM – One way to start a deep tech spin-off from research** — •Max Fries
MA 25.2	Wed	10:00–10:30	HSZ 04	**Spin-Ion Technologies : taking the research from a lab to a start-up company** — •Dafiné Ravelosona
MA 25.3	Wed	10:30–11:00	HSZ 04	**MagREEsource : the green Rare Earth Magnet company** — •Sophie Rivoirard, Erick Petit
MA 25.4	Wed	11:00–11:30	HSZ 04	**THATec Innovation – we automate your lab** — •Thomas Sebastian
MA 25.5	Wed	11:30–12:00	HSZ 04	**Kiutra: Magnetic refrigeration for science and technology** — •Alexander Regnat, Jan Spallek, Tomek Schulz, Christian Pfleiderer
MA 26.1	Wed	9:30–10:00	HSZ 401	**The self-induced spin glass: the perplexing magnetism of elemental neodymium** — •Alexander Khajetoorians
MA 30.1	Wed	15:00–15:30	HSZ 02	**Femto- phono- magnetism** — •Sangeeta Sharma
MA 30.2	Wed	15:30–16:00	HSZ 02	**Spin-switchable molecules in interaction with their environment.** — •Cyrille Barreteau
MA 30.3	Wed	16:15–16:45	HSZ 02	**Yep, real photodoping.** — Lukas Gierster, •Julia Stähler
MA 30.4	Wed	16:45–17:15	HSZ 02	**Probing ultrafast magnetization thanks to ultrashort soft X-ray pulses** — •Emmanuelle Jal
MA 34.1	Thu	9:30–10:00	HSZ 02	**Polarized phonons carry angular momentum in ultrafast demagnetization** — •Peter Baum
MA 34.2	Thu	10:00–10:30	HSZ 02	**Spin-phonon coupling in ordered magnets: origin and consequences** — •Akashdeep Kamra
MA 34.3	Thu	10:30–11:00	HSZ 02	**Magnon-mechanics in high overtone acoustic resonators** — •Hans Huebl

MA 34.4	Thu	11:15–11:45	HSZ 02	**Cavity Magnomechanics: Harnessing the Magnomechanical Coupling for Applications in the Microwave and Optical Regimes** — •Silvia Viola Kusminskiy
MA 34.5	Thu	11:45–12:15	HSZ 02	**Coherent spin-wave transport in an antiferromagnet** — •Andrea Caviglia
MA 41.1	Thu	15:00–15:30	HSZ 02	**Altermagnetism and spin symmetries** — •Libor Šmejkal
MA 41.2	Thu	15:30–16:00	HSZ 02	**Spontaneous Hall effect in Mn5Si3 altermagnet** — •H. Reichlova, R. Lopes Seeger, R. González-Hernández, I. Kouta, R. Schlitz, D. Kriegner, P. Ritzinger, M. Lammel, M. Leiviska, V. Petricek, E. Schmoranzerova, A. Badura, A. Thomas, V. Baltz, L. Michez, J. Sinova, S.T.B. Goennenwein, T. Jungwirth, L. Smejkal
MA 41.5	Thu	16:30–17:00	HSZ 02	**Generation of tilted spin-current by the collinear antiferromagnet RuO2** — •Arnab Bose
MA 41.6	Thu	17:00–17:30	HSZ 02	**First-principles studies on the anomalous transport properties of ferromagnets, antiferromagnets, and altermagnets** — •Wanxiang Feng
MA 41.7	Thu	17:30–18:00	HSZ 02	**Insight into chemical and magnetotransport properties of epitaxial α-Fe2O3/Pt bilayers** — •Anna Kozioł-Rachwał, Natalia Kwiatek, Witold Skowroński, Krzysztof Grochot, Jarosław Kanak, Ewa Madej, Kinga Freindl, Józef Korecki, Nika Spiridis

Invited Talks of the joint Symposium SKM Dissertation Prize 2023 (SYSD)

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	9:30–10:00	HSZ 04	**Diffusion of antibodies in solution: from individual proteins to phase separation domains** — •Anita Girelli
SYSD 1.2	Mon	10:00–10:30	HSZ 04	**Intermediate Filament Mechanics Across Scales** — •Anna V. Schepers
SYSD 1.3	Mon	10:30–11:00	HSZ 04	**Ultrafast Probing and Coherent Vibrational Control of a Surface Structural Phase Transition** — •Jan Gerrit Horstmann
SYSD 1.4	Mon	11:00–11:30	HSZ 04	**Electro-active metasurfaces employing metal-to-insulator phase transitions** — •Julian Karst
SYSD 1.5	Mon	11:30–12:00	HSZ 04	**The role of unconventional symmetries in the dynamics of many-body systems** — •Pablo Sala

Invited Talks of the joint Symposium Green Magnets for Efficient Energy Conversion (SYGM)

See SYGM for the full program of the symposium.

SYGM 1.1	Mon	15:00–15:30	HSZ 01	**Data mining protocols for functional magnetic materials** — •olle Eriksson
SYGM 1.2	Mon	15:30–16:00	HSZ 01	**High performance permanent magnets; elements criticality, new demands, and extrinsic magnetic properties** — •Hossein Sepehri-Amin, Xin Tang, Tadakatsu Ohkubo, Kazuhiro Hono
SYGM 1.3	Mon	16:00–16:30	HSZ 01	**Magnetic shape memory Heuslers: microstructure-related effects on the martensitic transformation** — •Franca Albertini
SYGM 1.4	Mon	16:45–17:15	HSZ 01	**Thin film combinatorial studies of hard magnetic materials** — •Nora Dempsey
SYGM 1.5	Mon	17:15–17:45	HSZ 01	**Magnetocaloric materials for energy-efficient thermal control systems** — •Victorino Franco, Aun N. Khan, Jorge Revuelta-Losada, Álvaro Díaz-García, Luis M. Moreno-Ramírez, Jia Yan Law

Invited Talks of the joint Symposium Real-Time Measurements of Quantum Dynamics (SYQD)

See SYQD for the full program of the symposium.

SYQD 1.1	Thu	9:30–10:00	HSZ 01	**Real-time measurement and control of spin dynamics in quantum dots** — •Seigo Tarucha
SYQD 1.2	Thu	10:00–10:30	HSZ 01	**Quantum Dot arrays for Quantum Information Transfer** — •Gloria Platero, David Fernandez-Fernandez, Juan Zurita

SYQD 1.3	Thu	10:30–11:00	HSZ 01	**Optical Detection of Real-Time Quantum Dynamics in Quantum Dots** — •Martin Geller, Jens Kerski, Eric Kleinherbers, Jürgen König, Annika Kurzmann, Pia Lochner, Axel Lorke, Arne Ludwig, Hendrik Mannel, Philipp Stegmann, Andreas Wieck, Marcel Zöllner
SYQD 1.4	Thu	11:30–12:00	HSZ 01	**Cooper Pair Splitting in Real-Time** — •Christian Flindt
SYQD 1.5	Thu	12:00–12:30	HSZ 01	**Trajectory-based detection in stochastic and quantum thermodynamics** — •Jukka Pekola

Invited Talks of the joint Symposium Topological Superconductor-Magnet Heterostructures (SYTS)

See SYTS for the full program of the symposium.

SYTS 1.1	Thu	15:00–15:30	HSZ 01	**Blending of superconductivity and magnetism via topological solitons** — •Christos Panagopoulos
SYTS 1.2	Thu	15:30–16:00	HSZ 01	**Topological landscaping in magnet-superconductor heterostructures** — •Sebastián A. Díaz
SYTS 1.3	Thu	16:00–16:30	HSZ 01	**Experimental study of minigaps and end states in bottom-up designed multi-orbital Shiba chains** — •Jens Wiebe
SYTS 1.4	Thu	16:45–17:15	HSZ 01	**Quantum spins and hybridization in artificially-constructed chains of magnetic adatoms on superconducting 2H-NbSe$_2$** — •Katharina J. Franke
SYTS 1.5	Thu	17:15–17:45	HSZ 01	**Braiding of Majorana zero modes** — •Stephan Rachel

Invited Talks of the joint Symposium Physics of van der Waals 2D Heterostructures (SYHS)

See SYHS for the full program of the symposium.

SYHS 1.1	Fri	9:30–10:00	HSZ 01	**Novel moiré excitons and ultrafast optical dynamics in van der Waals 2D heterostructures** — •Steven G. Louie
SYHS 1.2	Fri	10:00–10:30	HSZ 01	**Interaction induced magnetism in 2D semiconductor moiré superlattices** — •Xiaodong Xu
SYHS 1.3	Fri	10:30–11:00	HSZ 01	**Ions in tight places: intercalation and transport of ions in van der Waals heterostructures** — •Irina Grigorieva
SYHS 1.4	Fri	11:15–11:45	HSZ 01	**Spin-orbit proximity in van der Waals heterostructures** — •Felix Casanova
SYHS 1.5	Fri	11:45–12:15	HSZ 01	**Plethora of many-body ground states in magic angle twisted bilayer graphene** — •Dmitri Efetov

Sessions

MA 1.1–1.4	Sun	16:00–18:00	HSZ 04	**Tutorial: Strategic elements and sustainability (joint session MA/TUT)**
MA 2.1–2.8	Mon	9:30–12:00	HSZ 02	**Skyrmions I**
MA 3.1–3.11	Mon	9:30–12:30	HSZ 401	**Magnetic Materials for Efficient Energy Conversion**
MA 4.1–4.14	Mon	9:30–13:00	HSZ 403	**Spin Transport and Orbitronics, Spin-Hall Effects (joint session MA/TT)**
MA 5.1–5.6	Mon	9:30–11:00	POT 6	**Thin Films: Magnetic Coupling Phenomena / Exchange Bias**
MA 6.1–6.6	Mon	14:30–17:05	POT 51	**Focus: Dislocations in Ceramics: Mechanics, Structures and Functionality (joint session KFM/MA)**
MA 7.1–7.12	Mon	15:00–18:00	HSZ 02	**Computational Magnetism**
MA 8.1–8.11	Mon	15:00–18:00	HSZ 04	**Ultrafast Magnetization Effects I**
MA 9.1–9.10	Mon	15:00–17:45	HSZ 401	**Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions**
MA 10.1–10.8	Mon	15:00–17:15	HSZ 403	**Topological Insulators (joint session MA/TT)**
MA 11.1–11.6	Mon	15:00–16:45	POT 6	**Non-Skyrmionic Magnetic Textures I**
MA 12.1–12.8	Tue	9:30–11:30	HSZ 02	**Skyrmions II**

MA 13.1–13.9	Tue	9:30–13:15	HSZ 03	**Focus Session: New Perspectives for Adiabatic Demagnetization Refrigeration in the Kelvin and sub-Kelvin Range (joint session TT/MA)**
MA 14.1–14.7	Tue	9:30–11:45	HSZ 04	**Surface Magnetism**
MA 15.1–15.5	Tue	9:30–11:50	HSZ 401	**INNOMAG e.V. Prizes 2023 (Diplom-/Master and Ph.D. Thesis)**
MA 16.1–16.9	Tue	9:30–12:00	HSZ 403	**Magnonics**
MA 17.1–17.6	Tue	9:30–11:00	POT 6	**Thin Films: Magnetic Anisotropy**
MA 18.1–18.8	Tue	15:00–17:15	HSZ 02	**Functional Antiferromagnetism I**
MA 19.1–19.7	Tue	15:00–17:00	HSZ 04	**Molecular Magnetism I**
MA 20.1–20.10	Tue	15:00–17:45	HSZ 401	**Spintronics (other effects)**
MA 21.1–21.8	Tue	15:00–17:15	HSZ 403	**Spin-Dependent Phenomena in 2D**
MA 22.1–22.5	Tue	15:00–16:15	POT 6	**Terahertz Spintronics**
MA 23.1–23.80	Tue	17:00–19:00	P1	**Poster Magnetism I**
MA 24.1–24.6	Wed	9:30–11:00	HSZ 02	**Molecular Magnetism II**
MA 25.1–25.5	Wed	9:30–12:30	HSZ 04	**Focus Session: Startups in Magnetism**
MA 26.1–26.6	Wed	9:30–11:30	HSZ 401	**Non-Skyrmionic Magnetic Textures II**
MA 27.1–27.7	Wed	9:30–11:30	HSZ 403	**Electron Theory of Magnetism and Correlations**
MA 28.1–28.5	Wed	9:30–10:45	POT 6	**Bulk Materials: Soft and Hard Permanent Magnets**
MA 29.1–29.5	Wed	11:30–12:45	HSZ 02	**Neuromorphic Magnetism / Magnetic Logic**
MA 30.1–30.4	Wed	15:00–18:00	HSZ 02	**PhD Focus Session: Non-equilibrium dynamics in theory and experiment**
MA 31.1–31.8	Wed	15:00–17:15	HSZ 04	**Functional Antiferromagnetism II**
MA 32.1–32.6	Wed	15:00–16:30	HSZ 401	**Magnetic Imaging Techniques I**
MA 33.1–33.8	Wed	15:00–17:15	HSZ 403	**Frustrated Magnets I**
MA 34.1–34.8	Thu	9:30–13:00	HSZ 02	**Focus Session: Spin-Phonon Coupling**
MA 35.1–35.9	Thu	9:30–12:00	HSZ 04	**Skyrmions III**
MA 36.1–36.6	Thu	9:30–11:00	HSZ 401	**Magnetic Particles / Clusters**
MA 37.1–37.6	Thu	9:30–11:00	HSZ 403	**Magnetic Heuslers**
MA 38.1–38.5	Thu	11:30–12:45	HSZ 401	**Micro- and Nanostructured Magnetic Materials**
MA 39.1–39.5	Thu	11:30–12:45	HSZ 403	**Weyl Semimetals**
MA 40.1–40.66	Thu	14:00–16:00	P2/EG	**Poster Magnetism II**
MA 41.1–41.7	Thu	15:00–18:00	HSZ 02	**Focus Session: Altermagnetism: Transport, Optics, Excitations**
MA 42.1–42.10	Thu	15:00–17:45	HSZ 04	**Caloric Effects in Ferromagnetic Materials**
MA 43.1–43.7	Thu	15:00–16:45	HSZ 401	**Magnetic Imaging Techniques II**
MA 44.1–44.9	Thu	15:00–17:30	HSZ 403	**Frustrated Magnets II**
MA 45	Thu	18:00–19:00	HSZ 04	**Members' Assembly**
MA 46.1–46.13	Fri	9:30–12:45	HSZ 02	**Ultrafast Magnetization Effects II**
MA 47.1–47.11	Fri	9:30–12:30	HSZ 04	**Skyrmions IV**
MA 48.1–48.8	Fri	9:30–11:45	HSZ 401	**Magnetic Instrumentation and Characterization**
MA 49.1–49.8	Fri	9:30–11:45	HSZ 403	**Magnetic Information Technology, Recording, Sensing**
MA 50.1–50.7	Fri	9:30–11:15	POT 6	**Magnetic Domain Walls (non-skyrmionic)**

Members' Assembly of the Magnetism Division

Thu 18:00–19:00 HSZ 04

MA 1: Tutorial: Strategic elements and sustainability (joint session MA/TUT)

Our appetite for resources is insatiable. The path to a climate-neutral society and economy requires the increasingly intensive use of strategy metals such as lithium, cobalt, nickel, but also the group of rare earth elements. This major transformation is not possible without the sustainable use of these so-called critical elements along the entire value chain. In the Tutorial "Strategic elements and sustainability", we have four eminent speakers looking in this context at new developments in batteries, catalysis, thermoelectrics and magnetism.

Organizers: Oliver Gutfleisch (TU Darmstadt) and Heiko Wende (U. Duisburg-Essen).

Time: Sunday 16:00–18:00 Location: HSZ 04

Invited Talk MA 1.1 Sun 16:00 HSZ 04

Making better batteries? – From Li-ion to Na-ion batteries — •Philipp Adelhelm — Humboldt-University Berlin, Berlin, Germany — Helmholtz-Zentrum Berlin, Berlin, Germany

The shift to electromobility is one of the most important transformations currently taking place in our society. This is associated with a sharp increase in battery production, which on the one hand opens up new opportunities, but on the other hand also has a massive impact on raw material supply and supply chains. In addition, new large markets are emerging, such as stationary energy supply or mobile robotics. Lithium-ion batteries are currently the most attractive technology for this. However, due to the large demand for batteries and the different application scenarios, other technologies are also being pursued. Sodium ion batteries can be produced on the same production lines as lithium ion batteries and are therefore considered a "drop-in" technology. The aim here is to replace not only costly lithium but also other expensive elements such as nickel or copper. Work is therefore being done worldwide on a cell chemistry for sodium ion batteries that works almost as well as lithium ion technology, but at the same time is cheaper and more readily available, or has other specific advantages. The tutorial gives an introduction to sodium ion technology. The motivation and state-of-the art are explained in more detail and material aspects are discussed. In particular, the question is addressed which electrode materials are promising for sodium ion batteries, what is needed to achieve further progress and what actually happens when lithium ions are replaced by sodium ions in a battery.

Invited Talk MA 1.2 Sun 16:30 HSZ 04

Sustainable Thermoelectric Materials Predicted by Data Mining and Machine Learning — •Kornelius Nielsch — Leibniz Institute of Solid States and Materials Research, Dresden, Germany — Institute of Materials Research at TU Dresden, Germany — Institute of Applied Physcis at TU Dresden, Germany

Generating electricity from temperature differences has proven itself in space. Thanks to this technology, the Voyager probes launched in 1977 are still sending signals today. In the meantime, the car industry and ship producers have become interested in thermoelectrics. The combustion of fossil fuels produces exhaust gas that is up to 1300 °C hot. Modern thermoelectric materials are continuously expanding the fields of thermoelectric applications. The experimental search for new thermoelectric materials remains largely restricted to a limited number of successful chemical and structural families, such as chalcogenides, skutterudites and zintl phases. In principle, computational tools such as density functional theory (DFT) offer the possibility of directing experimental synthesis efforts towards very different chemical structures. In practice, however, predicting thermoelectric properties based on first principles remains a difficult endeavour, and experimental researchers do not usually use computations directly to drive their own synthesis efforts. Strategies to bridge this practical gap between experimental requirements and computational tools will be discuss und presented in this tutorial talk. Ref: Energy Environ. Sci. 14, 3559 (2021) and Advanced Theory and Simulations 5, 2200351 (2022)

Invited Talk MA 1.3 Sun 17:00 HSZ 04

Design strategies for electrocatalysts – an electrochemist's perspective — •Kristina Tschulik — Ruhr-Universität Bochum, Faculty for Chemistry and Biochemistry, Chair for Electrochemistry and Nanoscale Materials — Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Straße 1, 40237 Düsseldorf

The aim to produce highly active, selective, and long-lived electrocatalysts by design drives major research efforts toward gaining fundamental understanding of the relationship between material properties and their catalytic performance. Surface characterization tools enable to assess atomic scale information on the complexity of electrocatalyst materials. Advancing electrochemical methodologies to adequately characterize such systems was less of a research focus point. In this tutorials, we shed light on the ability to gain fundamental insights into electrocatalysis and establish design strategies based on these. Concepts on how to improve mass transport, e.g. by exploiting magnetic fields are highlighted in this respect. Particular attention is paid to deriving design strategies for nanoelectrocatalysts, which is often impeded, as structural and physical material properties are buried in electrochemical data of whole electrodes. Thus, a second major approach focuses on overcoming this difference in the considered level of complexity by methods of single-entity electrochemistry. The gained understanding of intrinsic catalyst performance will ultimately allow us to advance design concepts to transforming "pre-catalysts" in the forseeable future.

Invited Talk MA 1.4 Sun 17:30 HSZ 04

Green magnetic materials for efficient energy, transport and cooling applications — •Oliver Gutfleisch — TU Darmstadt, Material Science, Functional Materials

High performance hard and soft magnets are key components of energy-related technologies, such as direct drive wind turbines and e-mobility. They are also important in robotics and automatization, sensors, actuators, and information technology. The magnetocaloric effect (MCE) is the key for new and disruptive solid state-based refrigeration. Magnetic hysteresis and its inherent energy product characterise the performance of all magnetic materials. In the 60th position of the periodic table of elements is neodymium - an element that belongs to the rare earth-lanthanides and essential for the above applications. Basic material requirements, figure of merits, demand and supply, criticality of strategic elements and their recycling are explained for both permanent magnets and magnetocalorics referring to the benchmark materials NdFeB and LaFeSi. Every battery needs a magnet. 95% of electric vehicles utilize rare earth magnet-based drive motors, the quantities required global will grow from 5.000 t in 2019 to about 40.000 - 70.000 t per anno in 2030. The material history of neodymium is exciting and complex; monopolistic mining in China under ruinous conditions is just as problematic as our dependence on it. How "green" are the metals for renewable technologies? Who pays which price for it, and when?

MA 2: Skyrmions I

Time: Monday 9:30–12:00 Location: HSZ 02

Invited Talk MA 2.1 Mon 9:30 HSZ 02

Two-dimensional Skyrmions in the real three-dimensional world — •Nikolai Kiselev — Institute for Advanced Simulation and Peter Grünberg Institute, Forschungsyentrum Jülich, 52425 Jülich Germany

Chiral skyrmions (CSs) emerging in noncentrosymmetric magnetic crystals are a prominent example of topological magnetic solitons – objects possessing properties of ordinary particles. In three-dimensional (3D) bulk samples, CSs usually form vortex-like strings penetrating the whole sample. Although CSs emerge as 3D objects, the two-dimensional (2D) model of a chiral magnet still represents a powerful tool for the theoretical study of CSs. In this talk, I'll present an overview of those phenomena predicted by the 2D model that found its experimental confirmation. In particular, I'll discuss the diversity of CSs with arbitrary topological charge [1] – skyrmions bags, the effect of turning skyrmions inside out [2], and the related phenomenon of skyrmion-antiskyrmion coexistence [3]. The discussion of the above phenomena is supported by a high-resolution transmission electron microscopy experiment. As an illustration of a phenomenon that cannot be described in a simplified 2D model, I'll present the theoretical and experimental study of so-called skyrmion braiding – the emergence of superstructures of skyrmion strings that wind around one another [4].

[1] F. N. Rybakov & N. S. Kiselev, Phys. Rev. B 99, 064437 (2019). [2] V. M. Kuchkin & N. S. Kiselev, Phys. Rev. B 101, 064408 (2020). [3] F. Zheng et al., Nature Phys. (2022) 18, 863 (2022). [4] F. Zheng et al., Nature Commun. 12, 5316 (2021).

MA 2.2 Mon 10:00 HSZ 02

Comparing Thiele-model computer simulations and experiments of skyrmion interactions and lattice formation — •Jan Rothörl[1], Yuqing Ge[1,2], Maarten A. Brems[1], Raphael Gruber[1], Mathias Kläui[1], and Peter Virnau[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Department of Physics, Chalmers University of Technology, Göteborg, Sweden

Magnetic skyrmions in thin films are often described as quasi-particles evolving according to the Thiele equation. Due to their effective 2D nature, their phase behavior can be compared to phase transitions described by the KTHNY theory. To allow for this analysis, we compare experimental and simulation results for skyrmion lattice formation [1] and determine skyrmion-skyrmion interaction potentials using the Iterative Boltzmann Inversion method [2]. These resulting potentials are then compared to the work describing the dependence of the kind of 2D phase transition on the shape of particle interactions [3].

[1] Zázvorka et al., Adv. Funct. Mater. 30 (46), 2004037 (2020). [2] Ge et al., arXiv:2110.14333 [cond-mat.mtrl-sci] (2021). [3] Kapfer, Krauth, Phys. Rev. Lett. 114 (3), 035702 (2015).

MA 2.3 Mon 10:15 HSZ 02

Machine learning based skyrmion detection with Kerr microscopy data — Isaac Labrie-Boulay[1], Thomas Winkler[1], Daniel Franzen[2], •Kilian Leutner[1], Alena Romanova[1], Hans Fangohr[3,4], and Mathias Kläui[1] — [1]Johannes Gutenberg University, Mainz, Institute of Physics, Staudinger Weg 7, Germany — [2]Johannes Gutenberg University, Mainz, Institute of Informatics, Staudinger Weg 9, Germany — [3]Max-Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]University of Southampton, SO17 1BJ, Southampton, United Kingdom

Magnetic skyrmions are topologically stabilized quasi-particles and are a potential enabler for unconventional computing devices [1]. A common method for detecting skyrmions is to use a Kerr microscope. Experimental data is affected by noise, low contrast, intensity gradients, or defects. Therefore, manual data treatment is necessary to evaluate the observations. To automatize Kerr microscopy data analysis, we have used a special type of convolutional neural network, called U-Net, to determine the shapes and positions of skyrmions [2]. Different methods were used to optimize the classification and to detect the skyrmions quickly with high reliability and to minimize manual work [3]. Our approach can also be extended to other magnetic structures, such as stripe domains or vortices.

[1] Klaus Raab et al., Nat. Commun. 13, 6982 (2022)
[2] Olaf Ronneberger et al., arXiv:1505.04597 [cs.CV] (2015)
[3] Isaac Labrie-Boulay et al. (in preparation)

MA 2.4 Mon 10:30 HSZ 02

Topological Hall effect in Pd/Fe/Ir(111) induced by electron scattering on magnetic skyrmions — •Adamantia Kosma[1], Philipp Rüssmann[2,3], Stefan Blügel[3], and Phivos Mavropoulos[1] — [1]Department of Physics, National and Kapodistrian University of Athens, Panepistimioupolis 15784, Athens, Greece — [2]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

This work comprises an ab-initio computational study of the topological Hall effect (THE) arising from magnetic skyrmions [1], which are formed in ultrathin films Pd/Fe/Ir(111) [2]. The investigation of the THE in these systems is of great importance, as it provides a way of electrically detecting magnetic skyrmions. We analyse the resistivity and the Hall angle of the system, which are calculated employing the non-collinear spin-density-functional theory within the full-potential relativistic Korringa-Kohn-Rostoker (KKR) Green function method combined with the semiclassical Boltzmann transport equation [3,4]. We discuss the dependence of the THE on additional electron scattering, modelled as random disorder broadening. Our findings predict a strong dependence of the topological Hall angle on the degree of disorder of a sample. [1] D. Maccariello et al., Nature Nanotechnology, vol. 13, 233-237 (2018). [2] N. Romming et al., Science, vol. 341, 6146, 2013. [3] https://jukkr.fz-juelich.de/. [4] A. Kosma et al., Phys. Rev. B, vol. 102, 144424.

15 min. break

MA 2.5 Mon 11:00 HSZ 02

Observation of the sliding mode of the magnetic texture in Fe/Ir(111) — •Wulf Wulfhekel[1], Hung-Hsiang Hang[1], Louise Desplat[2], Volodymyr Kravchuk[1], Marie Hervé[3], Timofey Balashov[4], Philipp Markus[1], Markus Garst[1], and Bertrand Dupé[5] — [1]Karlsruhe Institute of Technology, Karlsruhe — [2]IPCMS, Université de Strasbourg, Strasbourg — [3]Université Sorbonne, Paris — [4]RWTH Aachen, Aachen — [5]Université de Liège, Liège

The fourfold non-collinear spin texture of Fe on the sixfold surface of Ir(111) is known to be incommensurate along one of the diagonals of the unit cell, while it is commensurate along the other. As the periodicity of the spin texture is only a few atoms, the magnetic energy of the structure experiences the atomic lattice rather strongly. Theoretically, the sliding mode of the spin texture with respect to the crystal lattice becomes gapped in the commensurate direction while it stays soft along the incommensurate one. We report on a combined theoretical and experimental study of the sliding mode along the soft direction excited by microwave fields in the junction of a spin-polarized STM.

MA 2.6 Mon 11:15 HSZ 02

Chemical pressure tuning of a skyrmion lattice with giant topological Hall effect — •Leonie Spitz[1,2], Max Hirschberger[1], Shang Gao[1], Taro Nakajima[1,3], Christian Pfleiderer[2], Takahisa Arima[1,4], and Yoshinori Tokura[1] — [1]RIKEN CEMS, Wakoshi, Saitama 351-0198, Japan — [2]Physik-Department, Technical University of Munich, 85748 Garching, Germany — [3]Institute for Solid State Physics, University of Tokyo, Kashiwa 277-8581, Japan — [4]Department of Advanced Materials Science, University of Tokyo, Kashiwa, Chiba 277-8561, Japan

A skyrmion lattice accompanied by a large topological Hall effect was found in the centrosymmetric frustrated triangular lattice magnet Gd_2PdSi_3 [1]. In contrast to non-centrosymmetric compounds, the skyrmion spin-vortices are not stabilized by the Dzyaloshinskii-Moriya interaction, but rather by exchange frustration and the Ruderman-Kittel-Kasuya-Yosida interaction [2,3]. The nanometer-scale size of the skyrmions is a further novelty giving rise to a large emergent magnetic field. We study the effect of isoelectronic doping on Gd_2PdSi_3 to gain a deeper understanding of the material's magnetic and electronic properties. Via alloying we manipulate the lattice constants and polytypism of the structure [4]. We report the impact of chemical pressure tuning on the magnetic order and the topological Hall effect.

[1] T. Kurumaji, et al., Science 365, 914-918 (2019) ; [2] T. Okubo, et al., Phys. Rev. Lett. 108, 017206 (2012) ; [3] A. O. Leonov, et al., Nat. Commun. 6, 8275 (2015) ; [4] L. Spitz, et al., J. Am. Chem. Soc. 144, 16866-16871 (2022).

MA 2.7 Mon 11:30 HSZ 02

Relationship of charge and spin density waves in the skyrmion compound $EuGa_2Al_2$ — •Steven Gebel[1], Jaime Moya[2], Jochen Geck[1], and Marein Rahn[1] — [1]Institute for Solid State and Materials Physics, Technical University of Dresden, 01062 Dresden, Germany — [2]Department of Physics and Astronomy, Rice University, Houston, TX, 77005, USA

The interplay of spin and charge density waves (SDW/CDW) in rare earth intermetallics is a matter of great interest, since it may reveal a recipe of how to taylor an antiferromagnet to yield certain topological properties. The centrosymmetric skyrmion host series $Eu(Ga,Al)_4$ provides an ideal setting to explore this scenario: The electronic structure can be tuned by chemical and hydrostatic pressure, which induces CDWs, which, in turn, determine a landscape of frustrated itinerant electronic correlations. To clarify the origin and character of such nesting instabilities, we studied subtle structural variations with temperature and pressure, and related them to density functional structure calculations. As magnetic structure determinations of more members of the series become available, this may explain exactly which factors toggle the magnetism's topological character.

MA 2.8 Mon 11:45 HSZ 02

Influence of interlayer Dzyaloshinskii-Moriya interactions on magnetic textures — •Elena Vedmedenko — University of Hamburg

An overview of magnet/non-magnetic metal/magnet trilayers with strong interlayer Dzyaloshinskii-Moriya interactions promoting out-of-plane as well as in-plane chirality between the magnetic layers will be presented [1-2]. Magnetic structuring in systems with the interlayer as well as intralayer Dzyaloshinskii-Moriya interactions will be discussed. An emphasis on the topological stability of those objects will be made.

1. A. Fernandez-Pacheco, E. Y. Vedmedenko et al., Symmetry-breaking interlayer Dzyaloshinskii* Moriya interactions in synthetic antiferromagnets, Nature Mat. 18, 679 (2019)

2. J. A. Arregi, P. Riego, A. Berger, and E. Y. Vedmedenko, Large Interlayer Dzyaloshinskii-Moriya interactions across Ag-layers, submitted.

MA 3: Magnetic Materials for Efficient Energy Conversion

Time: Monday 9:30–12:30 Location: HSZ 401

MA 3.1 Mon 9:30 HSZ 401

Voltage-driven giant modulation of magnetism in ferro- and ferri-magnetic alloys — •Xinglong Ye[1,2], Harish Singh[1], Hongbin Zhang[1], Holger Gesswein[3], Reda Chellali[2], Ralf Witte[2], Alan Molinari[2], Konstantin Skokov[1], Oliver Gutfleisch[1], Horst Hahn[2], and Robert Kruk[2] — [1]Department of Material Science, Technical University Darmstadt — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology — [3]Institute of Applied Materials, Karlsruhe Institute of Technology

Controlling magnetism and magnetic properties by small voltages have become one of the core research topics vigorously pursued in magnetoelectric actuation, spintronics and data storage. In magnetically-ordered metals and alloys, however, the voltage effect is usually limited to the scale of atomic layers due to strong electric-field screening. Here, we propose to control their magnetism and magnetic properties by electrochemically-driven insertion/extraction of hydrogen atoms in interstitial sites. Using this approach, we have tuned the magnetocrystalline anisotropy and coercivity of SmCo5 with micrometer-sized particles by more than 1 T by applying voltages as low as 1 V. Consequently, a voltage-assisted and -controlled magnetization reversal has been achieved at room temperature for the first time in permanent magnets. Furthermore, we will show that our electrochemically-driven hydrogen charging can switch the perpendicular anisotropy to in-plane anisotropy in ferrimagnetic thin films with high anisotropy energy, which further exemplifies the universality of our approach in controlling magnetism of rare earth - containing materials.

MA 3.2 Mon 9:45 HSZ 401

Additive Manufacturing of (Pr,Nd)-Fe-Cu-B Permanent Magnets — •Jianing Liu[1], Ruiwen Xie[2], Alex Aubert[1], Lukas Schäfer[1], Holger Merschroth[3], Jana Harbig[3], Ying Yang[4], Philipp Gabriel[4], Anna Ziefuss[4], Stefan Barcikowski[4], Matthias Weigold[3], Hongbin Zhang[2], Oliver Gutfleisch[1], and Konstantin Skokov[1] — [1]Functional Materials, Technical University of Darmstadt — [2]Theory of Magnetic Materials, Technical University of Darmstadt — [3]Institute of Production Management, Technology and Machine Tools, Technical University of Darmstadt — [4]Technical Chemistry I, University of Duisburg-Essen

Additive Manufacturing (AM) of permanent magnets is a new and challenging field in material science and engineering. To obtain a microstructure necessary for high coercivity is by no means straightforward, especially after fast cooling in Laser Powder Bed Fusion (L-PBF). In order to achieve the desired microstructure and hard magnetic properties, we propose the Pr-Fe-Cu-B as a new useful reference alloy system and compare with its Nd-based counterpart. Our studies describe the L-PBF and the subsequent annealing optimization in order to understand the newly established coercivity mechanism. Specifically, we explore the 6-13-1-type grain boundary phase and grow single crystals to understand its magnetism, supported by DFT calculations. Furthermore, grain boundary engineering with nanoparticles shows great potential on grain refinement and uniaxial grain growth during re-solidification during L-PBF. We acknowledge the support of the Collaborative Research Centre/Transregio 270 HoMMage.

MA 3.3 Mon 10:00 HSZ 401

Simultaneous measurements of X-ray absorption, diffraction and bulk properties in $HoCo_2$ — •Katharina Ollefs[1], Gabriel Gomez-Eslava[1], Alex Aubert[2], Konstantin Skokov[2], Alexey Karpenkov[2], Oliver Gutfleisch[2], Fabrice Wilhelm[3], Andrei Rogalev[3], Damian Günzing[1], Johanna Lill[1], Benedikt Eggert[1], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Functional Materials, Technical University Darmstadt, Germany — [3]European Synchrotron Radiation Facility, France

Bulk properties and atomistic/local parameters determined by X-ray Absorption Spectroscopy (XAS) or scattering are typically measured on different samples (such as powder) with the same composition. Together with the influence of the different sample environments in different setups this prevents a direct correlation of microscopic and macroscopic observations, especially for materials exhibiting dramatic changes of their properties around phase transitions. Here we present the ULMAG [1] set up. To demonstrate the capability of our technique we measured, a polycrystalline $HoCo_2$ sample. We show the magnetic field dependence of X-ray Magnetic Circular Dichroism (XMCD), stray field, longitudinal and transversal strain and sample temperature. Furthermore we demonstrate the capability to measure XAS/XMCD and diffraction on a single grain inside this material. [1] Aubert, Alex, et al. IEEE Transactions on Instrumentation and Measurement 71 (2022): 1-9. Supported by the DFG CRC TRR 270 HoMMage, the BMBF project ULMAG and the ESRF by beamtime allocation.

MA 3.4 Mon 10:15 HSZ 401

A thorough TEM investigation of B2 ordered FeRh (50/50) alloy — •Esmaeil Adabifiroozjaei[1], Nagaarjhuna Kani[1,2], Robert Winkler[1], Tianshu Jiang[1], Oscar Recalde[1], Alexander Zintler[1], Alisa Chirkova[2], Konstantin Skokov[2], Oliver Gutfleisch[2], and Leopoldo Molina Luna[1] — [1]Advanced Electron Microscopy, Department of Materials- and Earth Sciences, Technical University of Darmstadt, Germany — [2]Functional Materials, Department of Materials- and Earth Sciences, Technical University of Darmstadt, Darmstadt, Germany

Fe50Rh50 alloys are known to have a B2 structure with an antiferromagnetic to ferromagnetic transition at near room temperature. Since this alloy can be considered as betta alloy (CdAu, TiNi, Fe-C, etc), it is expected to present a pre-martensite structure followed by a martensite structure upon cooling at cryogenic temperature. The martensite was also predicted by extensive first principal calculations. However, so far, no evidence has been given regarding the formation of either pre-martensite or martensite structures in the Fe50Rh50 alloy. Here, we use various TEM techniques (including CTEM, HRTEM, STEM (HAADF), and EDS) to investigate the FeRh 50/50 alloy and demonstrate that although the structure of the alloy matches the B2 BCC structure, there is systematic modulation along certain reflexes (100 and 110). We believe that the existence of such ordered modulation along certain directions are indicative of a pre-martensite structure.

MA 3.5 Mon 10:30 HSZ 401

Shaping and functionalizing of Gd for a magnetocaloric cooling application — •Lukas Beyer[1,2], Bruno Weise[1], Julia Kristin Hufenbach[1,2], and Jens Freudenberger[1,2] — [1]Leibniz IFW Dresden, Institute for Complex Materials, Helmholtzstr. 20, 01069, Dresden, Germany — [2]TU Bergakademie Freiberg, Institute of Materials Science, Gustav-Zeuner-Str. 5, 09599, Freiberg, Germany

Magnetic refrigeration based on the magnetocaloric effect aims to substitute conventional cooling solutions, still, shaping and use of magnetocaloric materials remains challenging [1]. A combination with so-called thermal switches could improve the heat transport resulting in higher operating frequencies and therefore, an increase in the power density of magnetic cooling [2]. This could be beneficial for battery thermal management systems [3]. In this work we studied the influence of mechanical deformation on Gd while producing Gd-substrates that could be combined with fast thermal switches by ElectroWetting On Dielectric. We prepared Gd-substrates via cold-rolling and strip casting and investigated these in regards of sufficient surface quality and substrate dimensions. Heat treatments have been performed to restore the magnetocaloric effect after deformation. By means of magnetic and heat-capacity measurements we calculated the isothermal entropy and adiabatic temperature change and proved the recovery of the magnetocaloric effect in Gd-substrates. [1] J. S. Brown, et al.;Appl. Therm. Eng. 64 (2014). [2] A. Kitanovski, et al.;Int.J. Refrig. 33 (2010). [3] J. Kim et al.;Appl. Therm. Eng. 149 (2019).

MA 3.6 Mon 10:45 HSZ 401

Large Room Temperature Anomalous Transverse Thermoelectric Effect in Kagome Antiferromagnet YMn6Sn6 — •Subhajit Roychowdhury[1], Andrew M. Ochs[2], Satya N. Guin[1], Kartik Samanta[1], Jonathan Noky[1], Chandra Shekhar[1], Maia G. Vergniory[1], Joshua E. Goldberger[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]The Ohio State University, Columbus, 43210 Ohio, United States

Kagome magnets possess several novel non-trivial topological features owing to the strong correlation between topology and magnetism, that extends to their applications in the field of thermoelectricity. Conventional thermoelectric (TE) devices use the Seebeck effect to convert heat into electrical energy. In contrast, transverse thermoelectric devices based on the Nernst effect are attracting recent attention due to their unique transverse geometry, which uses a single material to eliminate the need for a multitude of electrical connections compared to conventional TE devices. In this study, we obtain a large anomalous transverse thermoelectric effect of ~ 2 microV K-1 at room temperature in a kagome antiferromagnet YMn6Sn6 single crystal. The obtained value is larger than that of state-of-the-art canted antiferromagnetic (AFM) materials and comparable with ferromagnetic systems. The large anomalous Nernst effect (ANE) can be attributed to the net Berry curvature near the Fermi level.

15 min. break

MA 3.7 Mon 11:15 HSZ 401

Tailoring of thermal hysteresis in Ni-Mn-Sn shape memory alloys via microstructure design — •Franziska Scheibel[1], Chistian Lauhoff[2], Johannes Puy[1], David Koch[1], Philipp Krooss[2], Thomas Niendorf[2], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt, Darmstadt, Germany — [2]Universität Kassel, Kassel, Germany

Ferromagnetic shape memory alloys (FSMA) like Ni-Mn-Sn undergo a magneto-structural transition and show giant multicaloric properties. Thus, these materials are excellent for caloric refrigeration as an energy efficient, environmentally friendly and safe alternative for vapor compression cooling. However, tailoring of the inherent thermal hysteresis is essential for material development [1].

The hysteresis can be influenced by the microstructure (grain configuration and size, texture, defects, or internal stress) [2]. In this study, the grain size and arrangement have been modified by powder-based processing using spark-plasma sintering and additive manufacturing technique to tailor both the microstructure and the thermal hysteresis at the same time. The understanding of the relation between grain-size, texture, grain arrangement and multiple external stimuli is essential to develop materials with first-order magneto-structural transition transformation for multicaloric cooling.

This work was supported by the ERC Advanced Grant "Cool Innov" and the SFB-TRR270 "HoMMage".

[1] F. Scheibel et al., Energy Technol. 6, 1397 (2018)
[2] O. Gutfleisch et al., Phil. Trans. R. Soc. A 374: 20150308 (2016)

MA 3.8 Mon 11:30 HSZ 401

Impact of disorder on the vibrational and magnetic properties of Ni-Mn-(Sn,In) Heusler alloys — •Olga N. Miroshkina[1], Benedikt Eggert[1], Johanna Lill[1], Benedikt Beckmann[2], David Koch[2], Katharina Ollefs[1], Francesco Cugini[3], Massimo Solzi[3], Mojmir Šob[4], Martin Friák[4], Oliver Gutfleisch[2], Heiko Wende[1], and Markus E. Gruner[1] — [1]University of Duisburg-Essen, Duisburg, Germany — [2]Technical University of Darmstadt, Darmstadt, Germany — [3]University of Parma, Parma, Italy — [4]Czech Academy of Sciences, Brno, Czech Republic

Ni-Mn-Z with Z=In,Sn Heuslers are promising magnetocaloric systems to be employed in the magnetic cooling devices. In this respect, it is important to understand the influence of the main group element on the vibrational and magnetic properties of these materials. By combining large-scale density functional theory calculations with ^{119}Sn-NRIXS and Mössbauer spectroscopy, we disentangled the vibrational contributions of the Sn atoms in Ni_2MnSn. We found the evidence that inversion of optical modes at Γ involving the displacement of Ni and the heavier Z atoms predicted previously for other Ni-Mn-based Heuslers is also a property of Ni_2MnSn, while deviation between experimental spectra and simulations might be explained by site-disorder [1]. In turn, the variation of Z in combination with chemical disorder can be employed to control the magnetization of the transition metal sublattice [2]. This work is funded by DFG within CRC/TRR 270.

[1] O.N. Miroshkina, B. Eggert *et al.*, PRB (accepted) (2022).
[2] F. Cugini *et al.*, PRB 105, 174434 (2022).

MA 3.9 Mon 11:45 HSZ 401

Tailoring thermal hysteresis and microstructure of Ni-Mn-based Heusler alloys for multicaloric cooling applications — •Andreas Taubel[1], Franziska Scheibel[1], Lukas Pfeuffer[1], Benedikt Beckmann[1], Navid Shayanfar[1], Tino Gottschall[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]TUDarmstadt, Material Science, 64287 Darmstadt — [2]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, 01328 Dresden

Refrigeration based on the magnetocaloric effect (MCE) attracts a lot of attention since it can be more energy efficient and environmentally friendly than current vapor compression technology. The concept uses a solid-state magnetic material that heats up and cools down cyclically when exposed to a changing magnetic field. The problem of thermal hysteresis for efficient materials with a first-order phase transition can be overcome by applying stress as a second stimulus [1].

In this work, we develop Ni-Co-Mn-In and Ni-Co-Mn-Ti Heusler alloys towards using them in a novel multi-stimuli cooling concept. We investigated the influence of different microstructures from chemical variation and different processing routes on the magnetocaloric and elastocaloric performance of these materials [2,3]. The introduction of secondary phases significantly enhances the mechanical stability.

We acknowledge funding by ERC (Adv. Grant Cool Innov, GrantNo. 743116) and by DFG (CRC HoMMage, ID 405553726 *TRR 270)

[1] T. Gottschall et al., Nature Mat. 17, 929*934 (2018)
[2] L. Pfeuffer et al., Acta Materialia 217 1175157 (2021)
[3] A. Taubel et al., Acta Mater. 201, 425-434 (2020)

MA 3.10 Mon 12:00 HSZ 401

Influence of Cu addition and chemical order on the thermomagnetic properties of Ni-Mn-Ga-based films — •Lukas Fink[1,2,3], Kornelius Nielsch[2,3], and Sebastian Fähler[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, D-01328 Dresden, Germany — [2]Leibniz IFW Dresden, Institute for Metallic Materials, D-01171 Dresden, Germany — [3]TU Dresden, Institute of Materials Science, D-01062 Dresden, Germany

One way to harvest low-grade waste heat is a microscale thermomagnetic generator (TMG), which uses magnetocaloric films as active material. The high surface-to-volume ratio of thin films enables a fast heat transfer, increasing the cycling frequency and power density compared to bulk devices. Selecting the optimal active material is decisive for the efficiency of a TMG since it will determine the temperature regime and the cycling frequency. Recently Ni-Mn-based Heusler alloys were proposed as they can be prepared by standard thin-film technologies.

Here we use combinatorial growth of Cu alloyed Ni-Mn-Ga films and subsequent heat treatment for systematic optimization of thermomagnetic properties. We examine the key thermomagnetic properties like 1) the working temperature T^* and 2) the performance $\frac{\Delta M}{\Delta T}$ and correlate them with common properties like 3) crystal structure, 4) 1st and 2nd order transition and 5) spontaneous magnetization. Within our research, we can disentangle the effects of valence electron number e/a and chemical order. This work is funded by the DFG (FA453/14).

MA 3.11 Mon 12:15 HSZ 401

Study of the corrosion behaviour of Ni-Co-Mn-In Heusler — •Ulysse Rocabert, Lukas Pfeuffer, and Oliver Gutfleisch — Functional Materials Group, Department of Materials and Earth Sciences, Technische Universität Darmstadt, Alarich-Weiss-Straße 16, 64287 Darmstadt, Germany

Heusler materials are one of the promising material classes that are considered for their very useful magnetocaloric properties at room temperature. While their magnetic and mechanical properties have seen broad investigation, their electrochemical properties especially in aqueous environment remain largely unstudied. This study focuses on the characterization of such properties of Ni-Co-Mn-In alloys in different chemical environments and proposes a assessment on their implementation into refrigeration systems in comparison with LaFeSi-Mn alloys.

MA 4: Spin Transport and Orbitronics, Spin-Hall Effects (joint session MA/TT)

Time: Monday 9:30–13:00 Location: HSZ 403

MA 4.1 Mon 9:30 HSZ 403

Topological information device operating at the Landauer limit — •Ahmet Mert Bozkurt[1,2,3], Alexander Brinkman[4], and Inanc Adagideli[3,4] — [1]QuTech, Delft University of Technology, 2600 GA Delft, The Netherlands — [2]Kavli Institute of Nanoscience, Delft University of Technology, 2600 GA Delft, The Netherlands — [3]Faculty of Engineering and Natural Sciences, Sabanci University, Orhanli-Tuzla, Istanbul, Turkey — [4]MESA+ Institute for Nanotechnology, University of Twente, The Netherlands

We propose and theoretically investigate a novel Maxwell's demon implementation based on the spin-momentum locking property of topological matter. We use nuclear spins as a memory resource which provides the advantage of scalability. We show that this topological information device can ideally operate at the Landauer limit; the heat dissipation required to erase one bit of information stored in the demon's memory approaches $k_BT \ln 2$. Furthermore, we demonstrate that all available energy, $k_BT \ln 2$ per one bit of information, can be extracted in the form of electrical work. Finally, we find that the current-voltage characteristics of the topological information device satisfy the conditions of an ideal memristor.

MA 4.2 Mon 9:45 HSZ 403

Controlling 3D spin textures by manipulating sign and amplitude of interlayer DMI with electrical current — •Fabian Kammerbauer[1], Won-Young Choi[1], Freimuth Frank[1,2], 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

The recently discovered interlayer Dzyaloshinskii-Moriya interaction (IL-DMI) in multilayers with perpendicular magnetic anisotropy favors a canting of spins in the in-plane direction [1]. It could thus stabilize exciting spin textures such as Hopfions. A key requirement for nucleation is to control the IL-DMI and so, we investigate the influence of an electric current on the strength of the IL-DMI, as previously found for FMI. The IL-DMI is quantified using out-of-plane hysteresis loops while applying a static in-plane magnetic field at varied azimuthal angles. We observe a shift in the azimuthal dependence with increasing current, which is concluded to originate from the additional in-plane symmetry breaking introduced by the current flow. Fitting the angular dependence we demonstrate the presence of an additive current-induced term [3]. With this, an easily accessible possibility to manipulate 3D spin textures by current is realized.

[1] Han et al., Nat. Mater. 18, 703-708 (2019)
[2] Karnad et al., Phys. Rev. Lett. 121, 147203 (2018)
[3] Kammerbauer et al, arXiv:2209.01450 (2022)

MA 4.3 Mon 10:00 HSZ 403

Nonequilibrium dynamics in a spin valve with noncollinear magnetization — •Rudolf Smorka[1], Pavel Baláž[2], Michael Thoss[1], and Martin Žonda[3,1] — [1]University of Freiburg, Germany — [2]Institute of Physics of the Czech Academy of Sciences Prague, Czech Republic — [3]Charles University Prague, Czech Republic

Manipulation of magnetization by electric currents enables novel functions for spin-transfer torque devices. We study the nonequilibrium spin dynamics and spin-transfer torques in noncollinear spin-valve heterojunctions using a mixed quantum-classical Ehrenfest approach.

In an isolated valve for short spacer layers and weak spin-electron couplings, magnetization dynamics of the ferromagnetic layers is in agreement with the macrospin approximation. For large spacer layers, our quantum-classical approach predicts electron-induced spin relaxation. For intermediate electron-spin couplings, a change in the localization character of the electronic eigenstates from metallic-like to insulator-like leads to a reduced indirect exchange interaction between spins mediated by the conduction electrons. In a spin valve coupled to leads, spin relaxation times differ by several orders of magnitude depending on whether the DC bias is introduced by shifting the electrochemical potentials of both leads symmetrically about the equilibrium Fermi level of the spin valve (reminiscent of a gate-tunable junction) or by shifting the chemical potential of only one lead (as realized in a scanning tunneling microscope geometry).

[1] R. Smorka, P. Baláž, M. Thoss, M. Žonda, Phys. Rev. B 2022, 106, 144435.

MA 4.4 Mon 10:15 HSZ 403

Nonrelativistic spin currents in altermagnets — •Rodrigo Jaeschke-Ubiergo, Jairo Sinova, and Libor Šmejkal — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 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 (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 identify 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 RuO2 [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 T-odd, which makes it different from the conventional spin Hall effect. [1] Šmejkal et al., PRX, 12, 031042 (2022). [2] Šmejkal, et al. Sci.Adv 2020. [3] Gonzalez- Hernandez, et al. PRL 2021. [4] Šmejkal, et al. PRX 12, 011028 (2022).

MA 4.5 Mon 10:30 HSZ 403

Quantification and modulation of intrinsic spin transport in 5d transition metals — •Akash Bajaj, Reena Gupta, Andrea Droghetti, and Stefano Sanvito — School of Physics and CRANN, Trinity College Dublin, Dublin 2, Ireland

Spin-Hall effect (SHE) enables charge-to-spin conversion in heavy transition metals, such as Ta and Pt, with strong spin-orbit coupling

(SOC) strengths. It has been extensively studied as a viable mechanism for the development of next-generation spintronics-based nonvolatile memory devices. Numerous experimental and first-principles approaches have been devised to quantify the charge-to-spin conversion efficiency i.e., the spin-Hall angle (SHA), for the SHE. However, such approaches unavoidably involve interface contributions and, in general, extrinsic effects such as disorder and impurities, which are known to be less dominant than the bandstructure-only intrinsic contribution in such heavy metals. In this work, we use density functional theory combined with a bond-current-based non-equilibrium Green's functions approach to quantify the intrinsic SHAs of bulk elemental and thin-film models of 5d transition metals. We then computationally demonstrate a strategy for modulating the SHA within the same device, using Pt and Au as contrasting examples. Our computational work not only provides a quantitative estimation of the intrinsic SHAs for these materials, but also enables its theoretical understanding aimed towards the development of higher performance and power-efficient spintronics-based non-volatile memory devices.

MA 4.6 Mon 10:45 HSZ 403

Influence of Disorder at Insulator-Metal Interface on Spin Transport — Mahsa Alsadat Seyed Heydari, Wolfgang Belzig, and •Niklas Rohling — Department of Physics, University of Konstanz

Motivated by experimental work showing enhancement of spin transport between yttrium iron garnet and platinum by the thin antiferromagnetic insulator NiO [1] between them, we consider spin transport trough the interface of a non-magnetic metal and a ferro- or antiferromagnetically ordered insulator. The spin transport is carried by spin-polarized electrons in the metal and by magnons in the insulator. Spin current can be generated by a spin accumulation in the metal due to the inverse spin Hall effect, a microwave field exciting magnons in the insulator, or by a thermal gradient (spin Seebeck effect). The spin current can be computed using Fermi's Golden Rule [2]. For a perfectly clean interface, the in-plane momentum is conserved for the electron-magnon scattering events which govern the spin transport through the interface. We calculate how disorder-induced broadening of the scatting matrix elements with respect to the in-plane momentum influences the spin current. As a general result, we observe that for many experimental setups, one should expect a rather small effect of interface disorder on the measured spin current.

[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] Bender et al., Phys. Rev. Lett. 108, 246601 (2012)

MA 4.7 Mon 11:00 HSZ 403

Long-range orbital-Hall torques in Nb(or Ru)/Ni Heterostructures — Arnab Bose[1], Fabian Kammerbauer[1], •Rahul Gupta[1], Dongwook Go[2], Yuriy Mokrousov[1,2], Gerhard Jakob[1], and Mathias Kläui[1,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

We report a large orbital Hall torque (OHT) generated by Nb and Ru via strong dependence of torques on the ferromagnets, Ni, in Nb(Ru)/Ni heterostructures. We found the sign reversal of the damping-like torque in Nb/Ni. Moreover, the long-range orbital transport in the ferromagnet was revealed by the thickness dependences of Ni in Ni/Nb(or Ru) heterostructure, which are markedly different from the regular spin absorption in the ferromagnet that takes place within a few angstroms and thus it uniquely distinguishes OHT from the spin Hall torque. The experimentally measured effective orbital-Hall conductivities are found to be $6.1\times10^4\ \frac{\hbar}{2e}\ (\Omega\mathrm{m})^{-1}$ and $5.86\times10^4\ \frac{\hbar}{2e}\ (\Omega\mathrm{m})^{-1}$ for Nb and Ru, respectively, which is an order of magnitude higher than their measured spin Hall conductivities, as also confirmed by the density functional theory. This study opens a plethora of possibilities to further engineering the torques, utilizing the orbital degree of freedom.

MA 4.8 Mon 11:15 HSZ 403

Layer-resolved spin-orbit torque assisted magnetization dynamics in Pt/Co heterostructure — •Harshita Devda[1], András Deák[2], Leandro Salemi[3], Levente Rózsa[1], László Szunyogh[2], Peter M. Oppeneer[3], and Ulrich Nowak[1] — [1]Universität Konstanz, Konstanz, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]Uppsala University, Uppsala, Sweden

It is well known that the spin-orbit torque (SOT) mechanism is more reliable for current induced magnetization dynamics than the spin-transfer torque. The key phenomenon behind the SOT in heavy metal/ferromagnet (HM/FM) bilayers is attributed to the spin Hall effect (SHE) and the spin Rashba-Edelstein effect (SREE). However, the exact mechanism is still under debate. So far various works have studied the SOT-driven magnetic behavior in different magnetic systems, but the layer-resolved understanding of the SOT effect in the HM/FM bilayer due to spin-orbit coupling (SOC) in heavy metal is still lacking. We focus on current-induced magnetization dynamics in a Pt/Co bilayer assisted by the SOC in Pt. We use a multiscale model which links ab initio calculations with atomistic spin dynamics simulations. We implement a linear-response formalism to compute the electrically induced magnetic moments, caused by SHE in bulk and SREE at the interface, and utilize these in atomistic spin dynamics simulations. We analyse the layer-resolved behavior of both field-like and damping-like torques in FM and determine how they affect magnetization dynamics in ferromagnets.

MA 4.9 Mon 11:30 HSZ 403

Spin and orbital Edelstein effect in a bi- and trilayer system with Rashba interaction — •Sergio Leiva[1], Jürgen Henk[1], Ingrid Mertig[1], and Annika Johansson[2] — [1]Martin Luther University Halle-Wittenberg, 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 several systems with broken inversion symmetry [1-6].

In the present work, we calculate the current-induced spin and orbital magnetization for a bilayer and a trilayer system with Rashba interaction for the interface and the free-standing slab configurations. We use the modern theory of orbital magnetization [7] and the Boltzmann transport theory. We found a significantly larger orbital than spin effect, with a strong dependence on the model parameters, such as effective mass and spin-orbit coupling per layer. This dependence allows us to enhance and even revert the sign of the orbital effect.

[1] T. Yoda *et al.*, Sci. Rep., **5**, 12024 (2015).
[2] D. Go *et al.*, Sci. Rep. **7**, 46742 (2017)
[3] T. Yoda *et al.*, Nano Lett., **18**, 916 (2018).
[4] L. Salemi *et al.*, Nat. Commun. **10**, 5381 (2019)
[5] D. Hara *et al.*, Phys. Rev. B, **102**, 184404 (2020).
[6] A. Johansson *et al.*, Phys. Rev. Research, **3**, 013275 (2021).
[7] T. Thonhauser *et al.* Phys. Rev Lett. **95**, 137205 (2005).

MA 4.10 Mon 11:45 HSZ 403

Optical detection of the orbital Hall effect in a light metal Ti — •Young-Gwan Choi[1,2], Daegeun Jo[3], Kyung-Hun Ko[1], Dongwook Go[4,5], Kyung-Han Kim[3], Hee Gyum Park[6], Changyoung Kim[7,8], Byoung-Chul Min[6], Uri Vool[2], Gyung-Min Choi[1,9], and Hyun-Woo Lee[3,10] — [1]DOES, SKKU, Suwon, Korea — [2]MPI-CPfS, Dresden, Germany — [3]Physics, POSTECH, Pohang, Korea — [4]PGI and IAS, FZJ and JARA, Julich, Germany — [5]GSE Mainz, Mainz, Germany — [6]Center for Spintronics, KIST, Seoul, Korea — [7]Physics, SNU, Seoul, Korea — [8]CCES, IBS, Seoul, Korea — [9]CINAP, IBS, Suwon, Korea — [10]APCTP, Pohang, Korea

Electrical generation of the angular momentum current enables the development of novel memory devices, similar to spin current generation. Recently, it has been theoretically proposed that the orbital angular momentum (OAM) current can be driven by a charge current, called as the orbital Hall effect (OHE). Here we report evidence of the OHE, measured by magneto-optical Kerr effect microscopy. We detect large Kerr signals in one of the 3d transition metals, Ti, in which the high orbital Hall conductivity is predicted. We also find that the large OAM is accumulated by the OHE with a relaxation length ~70 nm. Moreover, we present the torque results in Ti/Ni. The high torque efficiency shows that the OAM injection allows for the electrical control of the magnetization. We also propose magnetic imaging using a nitrogen-vacancy scanning probe to measure OAM accumulation directly. Our results can pave the way for a deep understanding and provide techniques for generating and detecting orbital transport.

MA 4.11 Mon 12:00 HSZ 403

Spin and orbital Edelstein effects at oxide interfaces —

•Annika Johansson[1], Börge Göbel[2], Sara Varotto[3], Srijani Mallik[3], Ingrid Mertig[2], and Manuel Bibes[3] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany — [3]Unité Mixte de Physique, CNRS, Thales, Université Paris-Saclay, Palaiseau, France

The spin Edelstein effect (SEE) provides charge-spin interconversion in nonmagnetic systems with broken inversion symmetry [1,2]: An external electric field generates a charge current as well as a homogeneous spin density. Further, a finite current-induced magnetization originating from the electrons' orbital moments can be generated, which is called orbital Edelstein effect (OEE) [3-5]. In this talk, the SEE and OEE at $SrTiO_3$- and $KTaO_3$-based two-dimensional electron gases are discussed within a semiclassical Boltzmann approach [6-8]. The OEE is predicted to exceed its spin counterpart by one order of magnitude, which can be understood by a band-resolved analysis of the SEE and OEE. Further, we suggest design rules for Rashba-like systems to enhance spin-charge interconversion efficiencies.

[1] A. G. Aronov, Y. B. Lyanda-Geller, JETP Lett. **50**, 431 (1989) [2] V. M. Edelstein, Solid State Commun. **73**, 233 (1990) [3] T. Yoda *et al.*, Sci. Rep. **5**, 12024 (2015). [4] T. Yoda *et al.*, Nano Lett. **18**, 916 (2018). [5] L. Salemi *et al.*, Nat. Commun. **10**, 5381 (2019) [6] D. Vaz *et al.*, Nat. Materials **18**, 1187 (2019) [7] A. Johansson *et al.*, Phys. Rev. Research **3**, 013275 (2021) [8] S. Varotto *et al.*, Nat. Commun. **13**, 6165 (2022)

MA 4.12 Mon 12:15 HSZ 403

Anisotropic anomalous Hall effect in altermagnetic Mn_5Si_3 — •Miina Leiviskä[1], Rafael Lopes Seeger[1], Helena Reichlová[2,3], Ismaïla Kounta[4], Libor Šmejkal[5,3], Javier Rial[1], Sebastian Beckert[2], Antonín Badura[6,7], Isabelle Joumard[1], Dominik Kriegner[2,3], Eva Schmoranzerová[6], Jairo Sinova[5], Tomáš Jungwirth[3], Sebastian Goennenwein[7], Lisa Michez[4], and Vincent Baltz[1] — [1]Univ. Grenoble Alpes, CNRS, CEA, Grenoble INP, IRIG-SPINTEC, F-38000 Grenoble — [2]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany — [3]Institute of Physics, Czech Academy of Sciences, Prague, Czechia — [4]Aix-Marseille University, CNRS, CINaM, Marseille, France — [5]Institute for Physics, Johannes Gutenberg University Mainz, Mainz, Germany — [6]Department of Chemical Physics and Optics, Faculty of Mathematics and Physics, Charles University, Prague, Czechia — [7]Department of Physics, University of Konstanz, Konstanz, Germany

The altermagnetic epitaxial films of Mn_5Si_3 exhibit anomalous Hall effect (AHE) despite the vanishing net magnetization [1]. This can be explained by non-relativistic time-reversal symmetry breaking, which allows for momentum-locked alternating spin-splitting of the bands [2]. Here, we investigate the anisotropy of the AHE by varying both the external field and the current channel orientations. In both cases, we observe unconventional, anisotropic behaviour that deviates from the typical behaviour of ferromagnets.

[1] H. Reichlova et al. arXiv:2012.15651, (2020)
[2] L. Šmejkal et al. Phys Rev X 12, 031042 (2022)

MA 4.13 Mon 12:30 HSZ 403

Observation of nonreciprocal magnon Hanle effect — •Janine Gückelhorn[1,2], Sebastián de-la-Peña[3], Matthias Grammer[1,2], Monika Scheufele[1,2], Matthias Opel[1], Stephan Geprägs[1], Juan Carlos Cuevas[3], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], Akashdeep Kamra[3], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, BAdW, Garching, Germany — [2]Physik-Department, School of Natural Sciences, TUM, Garching, Germany — [3]IFIMAC and Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [4]Munich Center for Quantum Science and Technology, München, Germany

The realization of the magnon Hanle effect, which is based on the precession of magnon pseudospin about the equilibrium pseudofield, via electrically injected and detected spin transport in an antiferromagnetic insulator demonstrates its high potential for devices and as a convenient probe for the underlying spin interactions in antiferromagnets. Here, we observe a nonreciprocity in the magnon Hanle signal measured in hematite (α-Fe_2O_3) using two spatially separated platinum electrodes as spin injector/detector [1]. Interchanging their roles was found to alter the detected magnon spin signal. The recorded difference depends on the applied magnetic field and reverses sign when the signal passes its nominal maximum at the so-called compensation field. We explain these observations in terms of a spin transport direction-dependent pseudofield. The latter leads to a nonreciprocity, which is found to be controllable via the applied magnetic field.

[1] J. Gückelhorn *et al.*, arXiv:2209.09040 (2022).

MA 4.14 Mon 12:45 HSZ 403

Spontaneous anomalous Hall effect arising from an unconventional compensated magnetic phase in a semiconductor — •Dominik Kriegner[1,2], Ruben Dario Gonzalez Betancourt[1,2,3,4], Jan Zubáč[1,3], Rafael Julian Gonzalez Hernandez[5], Kevin Geishendorf[4], Gunther Springholz[6], Kamil Olejník[1], Jakub Železný[1], Libor Šmejkal[7], Andy Thomas[2,4], Helena Reichlová[1,2], Sebastian Tobias Benedikt Goennenwein[8], and Tomas Jungwirth[1,9] — [1]Institute of Physics, AV ČR, Prague, Czech Republic — [2]IFMP, TU Dresden — [3]Charles University, Prague — [4]IFW Dresden — [5]Universidad del Norte, Barranquilla, Colombia — [6]JKU Linz, Austria — [7]JGU, Mainz — [8]University of Konstanz — [9]University of Nottingham, United Kingdom

The anomalous Hall effect, commonly observed in metallic magnets, has been established to originate from the time-reversal symmetry breaking by an internal macroscopic magnetization in ferromagnets or by a non-collinear magnetic order. Here we observe a spontaneous anomalous Hall signal in the absence of an external magnetic field in an epitaxial film of MnTe, which is a semiconductor with a collinear antiparallel magnetic ordering of Mn moments and a vanishing net magnetization. The anomalous Hall effect arises from an unconventional phase with strong time-reversal symmetry breaking and alternating spin polarization in real-space crystal structure and momentum-space electronic structure.

R. D. Gonzalez Betancourt et al., arXiv:2112.06805

MA 5: Thin Films: Magnetic Coupling Phenomena / Exchange Bias

Time: Monday 9:30–11:00 Location: POT 6

MA 5.1 Mon 9:30 POT 6

Study of Amorphous CoFeB Film Interfaced with Heavy Metals using Magnetic Circular Dichroism in Hard X-Ray Photoemission — •A. Gloskovskii[1], C. Schlueter[1], M. Singh[2], S. K Vayalil[2], M. Gupta[3], V. R. Reddy[3], and A. Gupta[2] — [1]Photon Science, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Physics Department, University of Petroleum and Energy Studies, Dehradun, India — [3]UGC-DAE Consortium for Scientific Research, Indore, India

Heterostructures consisting of HM/CoFeB/HM (HM=Heavy Metal) are important for the development of low power spintronics, thanks to the phenomena like Interfacial Dzyaloshinskii-Moriya Interaction, spin Hall effect etc. The HM interface layers can significantly affect the magnetic properties as well as thermal stability of the CoFeB layer. In the present work, magnetic circular dichroism in hard X-ray photoemission (MCD-HAXPES) has been used to elucidate the possible difference in the electronic structure of Fe and Co atoms and the effect of interfacing HM layer on the same. Multilayers: Si(substrate)/HM 20nm/ $Co_{40}Fe_{43}B_{17}$ 10nm/HM 3nm/Al 3nm (HM=Mo, W) were deposited using magnetron sputtering. CoFeB layer is amorphous in nature. MCD-HAXPES measurements were done at beamline P22 of PETRA III, Hamburg, using 6 keV X-rays, falling at a grazing angle. The maximum asymmetry is found to be 39% for Fe and 23.6% for Co. Co spectrum has an additional weak shoulder at 4 eV from the main 2p line. This may be an indication of a correlation-induced satellite of majority spin nature in Co.

MA 5.2 Mon 9:45 POT 6

Ferromagnetic springs in exchange biased trilayers — •Sapida Akhundzada[1], Lukas Paetzold[1], Arne Vereijken[1], Christian Janzen[1], Thomas Saerbeck[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany — [2]Institut Laue-Langevin, Grenoble, France

Exchange springs or magnetic helices, consisting of multilayered thin film systems, exhibit spiral spin configurations during magnetization reversal [1]. By combining magnetically soft/hard bilayers [2] or exchanged biased ferromagnetic/antiferromagnetic layer systems [3], comparably short domain walls can be engineered, making these systems interesting for fundamental as well as applied research [1]. Here we show how magnetic order can be induced in exchange biased trilayer systems consisting of a single ferromagnetic layer embedded between two antiferromagnetic layers. The exchange coupling between the ferromagnet and one antiferromagnet is modified by light helium ion bombardment [4] leading to a trilayer system in which the exchange bias at the two ferromagnet/antiferromagnet interfaces points in different directions. The trilayer system is characterized by angular-resolved vibrating sample magnetometry revealing the existence of the spiral domain state in the designed layer system.

[1] A.C. Basaran, et al., MRS Bull. 40, 925 (2015).
[2] F. Magnus, et al., Nat. Commun. 7, (2016).
[3] A. Scholl, et al., Phys. Rev. Lett. 92, 18 (2004).
[4] T. Mewes, et al., Appl. Phys. Lett. 76, 1057 (2000).

MA 5.3 Mon 10:00 POT 6

Mesoscale Dzyaloshinskii-Moriya interaction in corrugated ultra-thin asymmetric magnetic layers — •Shahrukh Shakeel, Oleksii M. Volkov, Pavlo Makushko, Eduardo Sergio Oliveros Mata, Denise Erb, Shengqiang Zhou, Juergen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf e. V., 01328 Dresden, Germany

Asymmetrically sandwiching thin magnetic layers with perpendicular anisotropy and Dzyaloshinskii-Moriya interaction (DMI) produces chiral non-trivial textures, e.g. skyrmions and chiral domain walls, which exhibit unexplored application potential in logic and memory devices [1]. Conversely, extrinsic DMI is observed by breaking local inversion symmetry appearing in curvilinear structures of conventional materials [2]. Here, employing ion beam irradiation of SiO2 substrates we fabricate corrugated ultra-thin Cr2O3/Co/Pt asymmetric layer stacks with different geometric parameters. By means of magnetometric and transport measurements, we demonstrate the appearance and controllability of mesoscale DMI [3] by tuning geometric and material parameters of the system.

[1] O. M. Volkov et al., Phys. Rev. Appl. 15, 034038 (2021).
[2] O. M. Volkov et al., Phys. Rev. Lett. 123, 077201 (2019).
[3] O. Volkov et al., Sci. Rep. 8, 866 (2018).

MA 5.4 Mon 10:15 POT 6

Polycrystalline exchange-biased bilayers: Magnetically effective versus structural antiferromagnetic grain volume distribution — •Maximilian Merkel, Meike Reginka, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

The macroscopic magnetic characteristics of polycrystalline exchange-biased antiferromagnet/ferromagnet bilayers are generally determined by a complex interplay of several parameters that describe the structural and magnetic properties of the material system. [1] We demonstrate the possibility to determine averaged microscopic parameters from macroscopic magnetic quantities measured by vectorial Kerr magnetometry in comparison to an elaborate model. In particular, we estimated the magnetically effective antiferromagnetic grain size distribution, finding that it differs significantly from the structural one. [2] This indicates, that the antiferromagnetic order, being essential for the interface exchange coupling to the ferromagnetic layer, extends only over a part of the grains' structural volumes.

[1] Merkel et al., Phys. Rev. B 102, 144421 (2020)
[2] Merkel et al., Phys. Rev. B 106, 014403 (2022)

MA 5.5 Mon 10:30 POT 6

Spin current generation in 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 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 current generation by means of the spin Seebeck effect and spin pumping at ferromagnetic resonance. SQUID magnetometry and spin Hall magnetoresistance measurements support our observations [2]. [1] A. Chumak et al., Nat. Phys. 11, 453 (2015). [2] S. Becker et al., Phys. Rev. Appl., 16, 014047(2021).

MA 5.6 Mon 10:45 POT 6

In-situ monitoring of the electric-field induced switching process in Fe_3O_4/Nb:STO heterostructures — •Yifan Xu[1], Mai Hussein Hamed[1,2], Connie Bednarski-Meinke[1], Asmaa Qdemat[1], Steffen Tober[1], Emmanuel Kentzinger[1], Ulrich Rücker[1], Oleg Petracic[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Faculty of Science,Helwan University,11795 Cairo,Egypt

The ability to tune magnetic oxide phases via redox reactions across their heterointerfaces could lead to useful spintronic and memristive device applications. By applying a small electric field, oxidation/reduction occurs at the heterointerface and leads to a reversible phase transition. In this talk, we present the preparation and characterization of epitaxial (001)Fe_3O_4 thin films grown on TiO_2-terminated (001)Nb:STO via pulsed laser deposition. Using magnetometry, we detect the Verwey transition; a strong indicator of the oxygen content in the Fe_3O_4 films. We observe the disappearance in the Verwey transition temperature with an applied positive electric field. This could be explained by oxygen diffusion through the interface which then leads to a reversible phase transition from Fe_3O_4(magnetite) to γ-Fe_2O_3(maghemite). Using ex-situ x-ray diffraction, we observe an additional Fe_3O_4(111) peak in the out-of-plane direction influenced by the applied voltage. Interestingly, by grazing-incidence small-angle X-ray scattering, we observe a change in the magnetite domain size for the sample after applying the electric field.

MA 6: Focus: Dislocations in Ceramics: Mechanics, Structures and Functionality (joint session KFM/MA)

Contrasting the common (mis)belief that ceramics are brittle, a new horizon of dislocation engineering in ceramics is being revealed, where dislocations are used to harness the mechanical and electro-functional properties. This session will bring together researchers who are interested in dislocations in ceramics, covering experiments and simulations, to stimulate new ideas for dislocation-based mechanics, characterization, and functionality in ceramics.

Chair: Dr. Xufei Fang (TU Darmstadt), Dr. Till Frömling (TU Darmstadt)

Time: Monday 14:30–17:05 Location: POT 51

Invited Talk MA 6.1 Mon 14:30 POT 51
Formation of conducting channels along of dislocations in $SrTiO_3$ — •Christian Rodenbücher[1], Kristof Szot[2], Gustav Bihlmayer[3], and Carsten Korte[1] — [1]Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK-14) — [2]University of Silesia, Institute of Physics, 41-500 Chorzów, Poland — [3]Forschungszentrum Jülich GmbH, Peter Grünberg Institut (PGI-1), 52425 Jülich, Germany

$SrTiO_3$ has become one of the most extensively studied metal oxides due to its exceptional electronic properties, which hold promising potential for applications in energy conversion and electronics. A key feature of $SrTiO_3$ is that its electronic transport properties are closely related to oxygen nonstoichiometry, which can be manipulated via redox reactions. Our nanoscale investigations on crystals and ceramics employing imaging techniques such as local-conductivity atomic force microscopy (LC-AFM) reveal that the reduction process is highly complex and heterogeneous on the nanoscale. Along extended defects such as dislocations there are easy reduction sites where oxygen vacancies are preferentially generated. In this way, filaments with high conductivity evolve around the dislocations in the originally insulating matrix and act as nanoscale short circuits. Upon application of mechanical stress, these filaments can even be moved through the crystal together with the dislocations. These findings not only can explain failure mechanisms in solid oxide electrolytes, but also raise fundamental questions regarding the mechanisms of electronic transport and superconductivity in self-doped transition metal oxides.

MA 6.2 Mon 15:00 POT 51
Dislocation engineering in oxides at room temperature: understanding the competition between plasticity and cracking — •Xufei Fang — Technical University of Darmstadt, Alarich-Weiss-Str. 2, 64287 Darmstadt, Germany

Dislocations in ceramic oxides are drawing increasing attention owing to their promising physical properties, such as dislocation-tuned electrical conductivity, thermal conductivity, and electro-mechanical properties. However, due to the brittleness of most oxides at room temperature, it remains a great challenge to engineer dislocations without forming cracks, which is a prerequisite for harnessing the functionalities. Here, we demonstrate dislocations can be effectively introduced into various ceramic oxides (SrTiO3, BaTiO3, KNbO3, TiO2) at room temperature by using nanoindentation pop-in stop tests. Interestingly, we find a size-dependent competition between purely dislocation-dominated plastic deformation under a critical tip radius and a concurrent appearance of cracks and dislocations when the tip radius is larger than a certain value. We further extend the deformation scale up to the millimeter regime and identify a reversal of the above size-dependent competition. We will address the underlying mechanisms by examining the dislocation nucleation, multiplication, and motion individually to shed new light on the dislocation mechanics in oxides, particularly at room temperature. Last but not least, the dislocation-tuned electrical and thermal conductivity will be briefly showcased using our developed methods for dislocation engineering.

MA 6.3 Mon 15:20 POT 51
Tuning dislocations in ferroelectric oxides by cyclic Indentation: dislocation toughening, domain fragmentation and phase stabilisation — •Oliver Preuss, Fangping Zhuo, Enrico Bruder, Christian Minnert, Jürgen Rödel, and Xufei Fang — Department of Materials and Earth Sciences, Alarich-Weiss-Str. 2, 64287 Darmstadt, Technical University of Darmstadt

In light of the growing research interest in dislocation-tuned functionality in ceramics, promising proofs-of-concept have been most recently demonstrated enhanced ferroelectric properties, electrical conductivity, and superconductivity. Yet introducing dislocations into brittle ceramics remains a grand challenge, especially at room temperature. Here, we demonstrate a simple method using a large Brinell indenter to cyclically indent the sample surface to tune the dislocation densities over 4 orders of magnitude (from 10^{10} m^{-2} up to 10^{14} m^{-2}) in single-crystal $KNbO_3$. A large, crack-free plastic zone (200 μm in diameter) is achieved on the sample surface at room temperature. More interestingly, both damage tolerance and fracture toughness have been improved. The interactions between dislocations and other microstructure features are examined in detail by optical microscopy, electron channelling contrast imaging, piezoresponse force microscopy methods and μ-Raman spectroscopy to shed light on the impact of dislocations on the mechanical properties as well as microstructural evolution. Our findings open new questions that may raise interest for further studies in ductile ceramics such as dislocation-domain wall interaction, domain wall fragmentation and strain-induced phase stabilisation.

15 min. break

Invited Talk MA 6.4 Mon 15:55 POT 51
Plastic properties of MgO : Insights from numerical modeling — •Philippe Carrez — Université de Lille, F-59000 Lille, France

Plastic properties of crystalline materials depend not only on the nature of the defects present in the crystal but also and more substantially on their mobilities and mutual interactions. This is typically the case for the creep properties of magnesium oxide (MgO), which has been the subject of numerous investigations over the years. Yet, the atomistic details of dislocation-point defects, dislocation-dislocation or dislocation-grain boundary interactions remain poorly described.

Nowadays, numerical modeling offers the possibility of modeling mechanical properties from the description of the elementary mechanisms of plasticity. As an example, we will discuss the interaction between 1/2<110>{110} dislocations and point defects in MgO. We will show how the edge dislocation core, within a region across the glide planes that expands over several Burgers vector, is a sink for vacancies, and thus enhances the pipe diffusion at moderate temperature. At higher temperature, point-defect absorption or emission along the dislocation lines allow the dislocation climb mechanism and can impact creep properties of MgO. We will thus show how atomic-scale simulations can elucidate the atomic configurations of the various jog configurations structure and give access to their formation energies.

MA 6.5 Mon 16:25 POT 51
Dislocation-tuned Schottky barrier in oxide ceramics — •Mehrzad Soleimany[1,2], Till Frömling[1], Lukas Porz[1], Enrico Bruder[1], Marin Alexe[2], and Jürgen Rödel[1] — [1]Department of Materials and Earth Sciences, Technical University of Darmstadt, 64287 Darmstadt, Germany — [2]Department of Physics, University of

Warwick, CV4 7AL Coventry, UK

For decades manipulation of interfaces and point defects in semiconductors have been the main focus of scientists for tuning the functional properties of materials. However, dislocations which are considered as one-dimensional defects, have not only been neglected but also tried to be avoided due to the assumption that they degrade desired properties of semiconductors. Nevertheless, it has recently been shown that this speculation can be challenged and dislocations can even be used to tune the thermal, electrical, and ferroelectric properties of materials, especially when they are introduced in high densities. In this work dislocation densities higher than 4× 10^{13} m^{-2} were introduced in a large volume of the n-type and p-type $SrTiO_3$ by mechanical deformation and cyclic loading. That has been confirmed via sample thinning and electron channeling contrast imaging. Utilizing electrochemical impedance spectroscopy and DC electrical measurements, we showed that based on doping, dislocations can reduce the Schottky barrier in the n-type $SrTiO_3$ by a factor of seven and can increase that by a factor of three in the p-type one.

MA 6.6 Mon 16:45 POT 51

Tailoring ceramic functional properties of YSZ with dislocations — •Till Frömling, Qaisar Muhammad, and Jürgen Rödel — 1Division of Nonmetallic-Inorganic Materials, Department of Materials and Earth Sciences, Technical University of Darmstadt, Alarich-Weiss-Str. 2, Darmstadt 64287, Germany

The defect chemistry of zirconia is usually modified by doping with high levels of yttrium. This induces a very high oxygen vacancy concentration which is responsible for the excellent ionic conductivity. There is a high demand for even better oxygen conductors because this would benefit applications like solid oxide fuel cells and solid state electrolyzers. Nevertheless, a limit has been reached concerning the doping strategy. Therefore, we suggestion to use dislocations as one-dimensional defects. These have so far been mostly disregarded as defects for modification of functional properties but are finding increasing attention recently. However, ceramics are generally brittle and thus not easily plastically deformable. Besides the difficulty of introducing dislocations into ceramics, their exact influence on functional properties is still unclear. Our investigations of yttria-stabilized zirconia show that mechanically introduced dislocations can enhance ionic conductivity significantly. This illustrates the opportunity to tune ceramics beyond what can be achieved by chemical doping.

MA 7: Computational Magnetism

Time: Monday 15:00–18:00 Location: HSZ 02

MA 7.1 Mon 15:00 HSZ 02

Quantitative theories of magnetic interactions in solids — •Attila Szilva[1], Yaroslav Kvashnin[1], Evgeny A. Stepanov[2], Lars Nordström[1], Olle Eriksson[1], Alexander I. Lichtenstein[3], and Mikhail I. Katsnelson[4] — [1]Uppsala University — [2]Institut Polytechnique de Paris — [3]Universität Hamburg — [4]Radboud University

The talk will summarize the review paper Quantitative theories of magnetic interactions in solids, by focusing on the derivation of the LKAG formula and the extension of the formalism for the case of non-collinear magnets. A first version of the paper can be read here: https://arxiv.org/abs/2206.02415. The paper reviews the method of explicit calculations of interatomic exchange interactions of magnetic materials. This involves exchange mechanisms normally refereed to as Heisenberg exchange, Dzyaloshinskii-Moriya interaction and anisotropic symmetric exchange. The connection between microscopic theories of the electronic structure, such as density functional theory or dynamical mean field theory, and interatomic exchange, is given in detail.

MA 7.2 Mon 15:15 HSZ 02

Magnetic Anisotropy and Ground States of α-$RuCl_3$ — •Seung-Ju Hong[1] and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, South Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, South Korea

In this talk, I will talk about the magnetic anisotropy of the Kitaev candidate α-$RuCl_3$. This material gained much attention due to its proximity to Kitaev spin liquid. Thus, there are many kinds of research that computed the anisotropic exchange parameters from first principles.

However, in our work, we conducted an unprecedented number of *ab initio* calculations with constrained density functional theory and total energy fitting. We both examined the monolayer and multilayer systems and computed the intra/inter-layer exchange parameters. Then, from Monte Carlo simulations, we compute the thermodynamical quantities. From these computations, we obtained a non-trivial results.

MA 7.3 Mon 15:30 HSZ 02

Modification of Magnetic Anisotropy at Organic-Inorganic Interfaces — •Anita Halder, Sumanta Bhandary, David O'Regan, Stefano Sanvito, and Andrea Droghetti — School of Physics and CRANN, Trinity College, Dublin 2, Ireland

The adsorption of nonmagnetic organic molecules on ferromagnetic materials offers an opportunity to tune their magnetic properties for promising applications in high-density data storage and spintronic devices. In this work, we report the manipulation of the magnetocrystalline anisotropy (MCA) of Co slabs through the adsorption of small molecules, such as benzene, cot etc. We consider a simple model based on 2nd-order perturbation theory to explain the modification of MCA due to molecular adsorption in a qualitative way. Further, we have used Density Functional Theory and the magnetic force theorem to calculate magnetic anisotropy. The results indicate that molecular adsorption tends to favour perpendicular MCA at surfaces by reducing in-plane MCA of the slab. A detailed analysis of various atom-resolved quantities demonstrates that the underlying physical mechanism is the metal-molecule interfacial hybridization, and, in particular, it is related to the chemical bond between the molecular p_z and the surface d_{z^2} orbitals. Generalizing the same argument, we also show that the complex molecules C_{60} and Alq_3 deposited on fcc-Co induce a similar modification of the in-plane MCA, and we related the results to recent experimental observations.

MA 7.4 Mon 15:45 HSZ 02

Strain dependence of magnetism in transition-metal phosphorus trichalcogenides — •Yang-Jun Lee[1,2,3], Tae Yun Kim[2], and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, Korea

Few-layer transition-metal phosphorus trichalcogenides (TMPX3) are two-dimensional (2D) antiferromagnetic materials, which have recently attracted attention because they can realize interesting 2D magnetic phenomena; they are considered materials whose magnetism can be described by the Heisenberg model, Ising model, or XY model depending on the transition metal ion. In this talk, we present the strain effects on the magnetism of TMPX3 compounds obtained from first principle calculations. Also, we will talk about the change in the symmetry and the magnetic model due to the strain.

MA 7.5 Mon 16:00 HSZ 02

Microscopic Insights for Beyond Room-Temperature Ferromagnetism in Two-Dimensional Fe5-xNixGeTe2 — •Sukanya Ghosh[1], Soheil Ershadrad[2], and Biplab Sanyal[3] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [3]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

The FenGeTe2 (n=3-5) (FGT) systems belong to the class of two-dimensional (2D) van der Waals (vdW) materials, promising candidates to explore magnetism in low-dimension with potential applications in spintronics. These systems are special due to their tunable structural, electronic and magnetic properties. Among the existing members of FGT family, Fe5GeTe2 has room temperature ferromagnetism with several intriguing properties. With the inclusion of dynamic electron correlation effect, our DFT+DMFT study shows how the spin moments, exchange interactions and Curie temperature (TC) of 2D Fe5-xGeTe2 can be varied significantly by substitutional doping with Ni. More importantly, the highest TC ~400 K is achieved for 20% doping concentration, beyond which the ferromagnetic order gets gradually suppressed. Our DFT+DMFT results are in good agreement with the experimental reports on bulk Fe5-xNixGeTe2 [1]. Moreover, we investigate the microscopic mechanisms responsible for the observed trend of TC in Fe5-xNixGeTe2 monolayer as an interplay between specific magnetic exchange interactions.

1. X. Chen et al, Phys. Rev. Lett. 128, 217203 (2022).

MA 7.6 Mon 16:15 HSZ 02

Efficient calculation of exchange interactions in magnetic materials — •Tae Yun Kim[1,2,3] and Cheol-Hwan Park[1,2,3] — [1]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, Korea — [2]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, Korea

Accurate description of the total energy of a magnetic system as a function of the local magnetic moments has always been a matter of importance, since it allows one to access the relevant low-energy excitation of the system, i.e. the magnon, which governs the low-temperature thermodynamics and remains important even at temperatures as high as the Curie temperature [1]. In this contribution, I will talk about an efficient way of calculating exchange interactions based on a constrained density functional theory method that captures accurately the magnetic total energy surface. As a concrete example, our ab-initio results on a magnetic system with substantial Dzyaloshinskii-Moriya interactions will be presented and be compared with that reported from previous studies to confirm the validity of our scheme.

[1] S. V. Halilov et al., Phys. Rev. B 58, 293 (1998)

MA 7.7 Mon 16:30 HSZ 02

Magnetic phases and stability of MPS4 — •Beatriz Costa Guedes[1], Thomas Brumme[2], Andrea Leon[3], and Thomas Heine[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Chair of Theoretical Chemistry, Technische Universität Dresden, Dresden, Germany — [3]Physics Faculty, Pontificia Universidad Católica de Chile, Santiago,Chile

The discovery of magnetic van der Waals materials provided a new playground for studying different aspects of magnetic interactions in reduced dimensions. Some interesting materials in this regard are the transition metal phosphorous chalcogenides MPS3 and CrPS4 (M = Mn, Fe, Co, and Ni), which are semiconductors exhibiting novel magnetic properties such as an intriguing dependence of the magnetic ordering on the transition metal (M). CrPS4 is particularly interesting because it exhibits a magnetic transition from antiferromagnetic (AFM) to ferromagnetic (FM) ordering in the monolayer limit, analog to the CrI3 compound, which is, in contrast, not stable in air. In this research, we study the stability and the electronic properties of the whole MPS4 family using density functional theory with a special focus on magnetic properties. Our results reveal a rich magnetic phase diagram with a complex electronic and magnetic dependence on M. They can be semiconductors, metals, or half-metals with AFM, FM, and non-magnetic configurations. We explain this behavior by discussing the interplay among structure, magnetism, and Coulomb interaction. By comparing it with the MPS3 system, we find some keys to understanding the magnetic properties of the MPS4 family.

MA 7.8 Mon 16:45 HSZ 02

Effect of Coulomb interaction on the magnetic properties of orthorhombic monolayer CrSBr — •Alexander Rudenko — Radboud University, Nijmegen, The Netherlands

Two-dimensional CrSBr is a recently discovered semiconducting spin-3/2 ferromagnet with the Curie temperature around 140 K. Unlike many other known 2D magnets, CrSBr has an orthorhombic lattice, giving rise, for instance, to spatial anisotropy of the magnetic excitations within the 2D plane. Theoretical description of CrSBr within the spin Hamiltonian approach turns out to be essentially nontrivial due to the complex character of the magnetic anisotropy resulting from low crystal symmetry. Here, we employ the Green's function formalism combined with first-principles calculations to systematically study magnetic properties of monolayer CrSBr. We find that the magnetic anisotropy and thermodynamical properties of CrSBr depend strongly on the Coulomb interaction and its external screening. In the free-standing limit, the system is close to an easy-plane magnet, whose long-range ordering is partially suppressed. On the contrary, in the regime of large external screening, monolayer CrSBr behaves like an easy-axis ferromagnet with more stable magnetic ordering. Our findings suggests that 2D CrSBr is an excellent platform for studying the effects of substrate screening on magnetic ordering.

MA 7.9 Mon 17:00 HSZ 02

Cu(VO)2(AsO4)2 with ferromagnetic V-V and antiferromagnetic Cu-V interactions — •Victoria Ginga[1,2], Alexander Tsirlin[1], and Oleg Siidra[2] — [1]Universität Leipzig, Felix Bloch Institute for Solid State Physics, Linnestraße 5, 04109 Leipzig — [2]St. Petersburg, Russia

Recent years have seen an increased interest in studying the magnetic properties of mineral-like compounds. The Cu(VO)2(AsO4)2 obtained by the CVT reaction method reproducing exhalative conditions has a new type of structure, which is characterized by layers formed by two [1+4+1]V4+-tOeq-[1+4+1]V4+ and one [1+4+1]V4+-vOeq-[1+4+1]V4+ linkages of V-centered octahedra. Arsenate groups decorate vanadate layers via corner-sharing with the VO6 octahedra, while single CuO6 octahedra are connecting vanadate layers into a framework via edge-sharing. Our ab initio calculations show that the magnetism of Cu(VO)2(AsO4)2 is dominated by the antiferromagnetic Cu-V coupling JCu-V = 257 K and the ferromagnetic V-V coupling JV-V =-277 K. This high energy scale is not uncommon in both Cu2+ and V4+ oxide compounds with the edge-shared octahedral geometry. Our results show the formation of unusual interaction geometries through the mixing of different spin-1/2 ions in the crystal structure. Experimental and computational results of the study of the Cu(VO)2(AsO4)2 with two distinct spin-1/2 magnetic ions will be presented.

MA 7.10 Mon 17:15 HSZ 02

SU(4) magnetism on a triangular moiré superlattice — •Lasse Gresista[1], Dominik Kiese[2], Michael Scherer[3] und Simon Trebst[1] — [1]Institute for Theoretical Physics, University of Cologne, Germany — [2]Center for Computational Quantum Physics, Simons Foundation Flatiron Institute, New York, USA — [3]Institute for Theoretical Physics III, Ruhr- University Bochum, Germany

The discovery of correlated insulating states in several graphene based moiré heterostructures such as trilayer graphene aligned with hexagonal boron nitride (TG/h-BN) has renewed the interest in strongly coupled electron systems where spin and orbital (or valley) degrees of freedom are intertwined. Considering the strong coupling limit, the localized degrees of freedom in such systems may be described by generators of SU(4) instead of the conventional SU(2) spin operators. Here, we study such an SU(4) 'spin-valley' model on a triangular lattice at a filling of two electrons (or holes) per moiré unit cell, with interactions that strongly break the SU(4) symmetry down to $SU(2)_{\text{spin}} \otimes U(1)_{\text{valley}}$. This is, e.g., relevant for the flat band physics of TG/h-BN within the topologically trivial regime. Using a pseudo-fermion functional renormalization group approach and semi-classical Monte Carlo calculations, we are able to distinguish parameter regimes showing no magnetic order, suggesting a spin-valley liquid or other quantum disordered ground state, and a multitude of classically ordered phases including ferromagnetic, antiferromagnetic, incommensurate and stripe order that manifests in different sectors of the coupled spin-valley space.

MA 7.11 Mon 17:30 HSZ 02

$YSrFeCrO_6$ as a Robust Ferromagnetic Semiconductor with Large Photovoltaic Efficiency — •Avijeet Ray, Paresh C. Rout, and Udo Schwingenschlögl — Physical Sciences and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

Semiconducting ferromagnetic transition metal oxides play a key role in spintronics applications. Employing first-principles calculations, we predict the existence of the double perovskite Y_2FeCrO_6 and study its properties. While both rock-salt (RS) and layered (L) structures are found to be dynamically stable, the L structure turns out to be energetically favorable. We determine the magnetic phase diagram under hydrostatic pressure. We find that the RS structure is dynamically stable and energetically favorable over the L structure in the case of $YSrFeCrO_6$ (hole doping by substitution of Y by Sr). $YSrFeCrO_6$ realizes a ferromagnetic ordering with a magnetic moment of 7 μ_B per formula unit, which is promising for spintronics applications. In addition, the ferromagnetic ordering is not compromised by hydrostatic pressure from -10 to 16 GPa. While the L structure of Y_2FeCrO_6 is an indirect bandgap semiconductor, the RS structure of $YSrFeCrO_6$ shows a direct bandgap of 0.90 eV (spin-orbit coupling taken into account in the calculation). We obtain a large spectroscopic limited maximum efficiency of 26% for $YSrFeCrO_6$, which is suitable for photovoltaic applications.

MA 7.12 Mon 17:45 HSZ 02

Magnetic Anisotropy of α-$RuCl_3$ — •Seung-Ju Hong[1], Tae Yun Kim[2], and Cheol-Hwan Park[1,2,3] — [1]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [2]Center for Correlated Electron Systems, Institute for Basic Science, Seoul 08826, South Korea — [3]Center for Theoretical Physics, Seoul National University, Seoul 08826, South Korea

α-$RuCl_3$ has gained much attention due to its proximity to Kitaev spin liquid. In this talk, we will discuss the magnetic anisotropy of α-$RuCl_3$. We performed first-principles calculations on the magnetic anisotropy of α-$RuCl_3$. We will compare the results of our first-principles calculations with available previous experimental and theoretical studies.

MA 8: Ultrafast Magnetization Effects I

Time: Monday 15:00–18:00 Location: HSZ 04

Invited Talk MA 8.1 Mon 15:00 HSZ 04

Optical control of antiferromagnetism — •Christian Tzschaschel — Department of Chemistry and Chemical Biology, Harvard University, USA

Antiferromagnets are a promising class of materials for novel spintronic applications. The absence of a net magnetization not only leads to a robustness of the magnetic state against magnetic fields but may also enable faster and potentially more energy efficient switching dynamics compared to their ferromagnetic counterparts. However, probing and controlling an antiferromagnetic state, in particular on ultrafast timescales, is a major challenge of antiferromagnetic spintronics.

Here, we will exploit magneto-optical and inverse magneto-optical effects to control antiferromagnetism. For example, the inverse Faraday effect, whereby circularly polarized light acts as a magnetic field in a material, allows us to selectively excite specific magnon modes in fully compensated antiferromagnets. The excitation mechanism can be based on a rotation of the antiferromagnetic vector or the generation of a net magnetization in the material. We will show that excitation mechanisms that induce a net magnetization exhibit a significantly higher efficiency. Moreover, we uncover a new inverse magneto-optical effect that allows us to deterministically induce an antiferromagnetic state in a magneto-electric antiferromagnet.

Our results demonstrate a high degree of optical control of antiferromagnetism, where we use light as both a probe and a handle to act on an antiferromagnetic state. We thus move closer to achieving a fundamental requirement for future ultrafast opto-spintronic devices.

MA 8.2 Mon 15:30 HSZ 04

Accelerating write/erase cycles in all-optical magnetization switching — •Felix Steinbach[1], Nele Stetzuhn[1], Daniel Schick[1], Dieter Engel[1], Unai Atxitia[2], Clemens von Korff Schmising[1], and Stefan Eisebitt[1,3] — [1]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy — [2]Dahlem Center for Complex Quantum Systems and Fachbereich Physik — [3]Institut für Optik und Atomare Physik, Technische Universität Berlin

All-optical switching of magnetic order presents a promising route toward faster and more energy efficient data storage. However, a realization in future devices is ultimately dependent on the maximum repetition rates of optically induced write/erase cycles. Here, we present two strategies to minimize the temporal separation of two consecutive femtosecond laser pulses to toggle the out-of-plane direction of the magnetization of ferrimagnetic rare-earth transition metal alloys. First, by systematically changing the heat transfer rates using either amorphous glass, crystalline silicon, or polycrystalline diamond substrates, we show that efficient cooling rates of the magnetic system present a prerequisite to accelerate the sequence of double pulse toggle switching. Second, we demonstrate that replacing the transition metal iron by cobalt leads to a significantly faster recovery of the magnetization after optical excitation allowing us to approach terahertz frequency of write/erase cycles with a minimum pulse-to-pulse separation of 7 ps [1].

[1] F. Steinbach et al., Appl. Phys. Lett. 120, 112406 (2022)

MA 8.3 Mon 15:45 HSZ 04

Variation of magnetic model parameters during ultrafast demagnetisation — •S. Polesya, S. Mankovsky, and H. Ebert — Department Chemie, Ludwig Maximilian University, Munich, Germany

Recent developments in time-dependent density functional theory (TD-DFT) paved the way towards investigating the ultrafast demagnetisation caused by a strong laser pulse on an *ab initio* level. However, the relaxation processes after a pump pulse still require to use phenomenological models that allow to account for different types of relaxation mechanisms on the basis of model parameters, that can be calculated from first principles. A stumbling block for such schemes is that the electronic structure is strongly out of equilibrium after the laser pulse and changes with time due to the relaxation. In the present work, we explore whether the parameters which determine the magnetization dynamics in this time regime can indeed be described on a first-principles level. This concerns first of all the exchange coupling, magnetic anisotropy and the Gilbert damping parameters that have been calculated for several transition metals using the spin-polarized relativistic Korringa-Kohn-Rostoker method. To account for the time evolution of the system, the calculations have been performed employing the TD-DFT potentials and occupation numbers generated by the Elk code [http://elk.sourceforge.net] for different time steps during the laser pulse and shortly after it, i.e. in the non-relaxed situation. In all cases a strong modification of the parameters compared to the equilibrium situation is found.

MA 8.4 Mon 16:00 HSZ 04

Temperature- and density-dependent spin-resolved coupling parameters in the μT-model — •Christopher Seibel, Sebastian T. Weber, Tobias Held, Sanjay Ashok, Hans Christian Schneider, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau

Since the first ultrafast demagnetization experiment by Beaurepaire *et al.* in 1996, many models have been developed. They reach from complex kinetic descriptions to simpler temperature-based models. The former consider the microscopic interactions between the individual (quasi-)particles involved and allow to extract coupling parameters of the individual interactions. These parameters can enter temperature-based models and depend on the nonequilibrium distribution, (quasi-)temperature, densities and the spin-dependent density of states [1,2,3]. However, these coupling parameters are often assumed to be constant in temperature-based models.

In this work, we investigate the influence of transient coupling parameters, like the electron-phonon coupling parameter, on the magnetization dynamics. The spin-resolved coupling parameter is calculated using complete Boltzmann collision integrals and depends on the transient temperatures and densities of the individual subsystems.

[1] Lin *et al.*, Phys. Rev. B **77**, 075133
[2] Mueller and Rethfeld, Phys. Rev. B. **87**, 035139
[3] Zahn *et al.*, Phys. Rev. Research **3**, 023032

MA 8.5 Mon 16:15 HSZ 04

Investigating the interplay of local electron correlations and ultrafast spin dynamics in fcc Ni at the European XFEL — •Tobias Lojewski — University of Duisburg-Essen

The interplay between exchange interaction, electron hopping and local Coulomb repulsion is of great interest as it influences the magnetic order in the 3d transition metals. We report the investigation of the electronic structure in fcc Nickel on the time scale of these interactions by combining the femtosecond time-resolved spectroscopic analysis of Nickel X-ray absorption spectra, measured at the SCS instrument of the European XFEL, with *ab initio* TD-DFT. We find a transient broadening and redshift of the $L_{2,3}$-edge absorption spectra, which we relate to electron repopulation and correlation-induced electronic structure modifications, demonstrating a time-dependent interaction between band formation, exchange interaction and Coulomb repulsion.

[1] T. Lojewski, M. F. Elhanoty, L. Le Guyader, O. Grånäs, N. Agarwal, C. Boeglin, R. Carley, A. Castoldi, C. David, C. Deiter, F. Döring, R. Y. Engel, F. Erdinger, H. Fangohr, C. Fiorini, P. Fischer, N. Gerasimova, R. Gort, F. de Groot, K. Hansen, S. Hauf, D. Hickin, M. Izquierdo, B. E. Van Kuiken, Y. Kvashnin, C. H. Lambert, D. Lomidze, S. Maffessanti, L. Mercadier, G. Mercurio, P. S. Miedema, K. Ollefs, M. Pace, M. Porro, J. Rezvani, B. Rösner, N. Rothenbach, A. Samartsev, A. Scherz, J. Schlappa, C. Stamm, M. Teichmann, P. Thunstrom, M. Turcato, A. Yaroslavtsev, J. Zhu, M. Beye, H. Wende, U. Bovensiepen, O. Eriksson and A. Eschenlohr, arXiv:2210.13162.

MA 8.6 Mon 16:30 HSZ 04

Laser-induced spin polarization on ultrafast time scales — •Oliver Busch, Franziska Ziolkowski, Ingrid Mertig, and Jürgen Henk — Institut für Physik, Martin-Luther-Universität, D-06099 Halle

In ultrafast spin dynamics one focuses often on demagnetization. However, the incident laser pulse should produce spin-polarized excited electrons – an effect ubiquitous in spin- and angle-resolved photoemission [1]. This laser-induced spin polarization certainly affects the ultrafast dynamics.

We study systematically the laser-induced spin polarization and its effect on the electron dynamics in Co/Cu heterostructures, modeled within our theoretical framework evolve [2]. The spin polarization depends strongly on polarization and angle of incidence of the femtosecond laser pulse, similar to photoemission [3]. Moreover, we find a significant spatial dependence, which underlines the importance of inhomogeneities in ultrafast spin dynamics.

[1] W. Schattke and M. A. Van Hove (eds.), *Solid-State Photoemission and Related Methods: Theory and Experiment* (Wiley-VCH, Weinheim, 2003)
[2] F. Töpler *et al.*, New J. Phys. **23** 033042 (2021)
[3] J. Henk *et al.*, J. Phys.: Condens. Matter **8** 47 (1996)

MA 8.7 Mon 16:45 HSZ 04

Finite-size effects in [Fe/MgO]n heterostructures on ultrafast timescales — •Moumita Kundu[1], Nico Rothenbach[2], Tobias Lojewski[2], Andrea Eschenlohr[2], Markus Gruner[2], Katharina Ollefs[2], Carolin Schmitz-Antoniak[3], Klaus Sokolowski-Tinten[2], William Windsor[4], Laurenz Rettig[4], Rossitza Pentcheva[2], Heiko Wende[2], Ulrich Nowak[1], and Uwe Bovensiepen[2] — [1]University of Konstanz, Konstanz, Germany — [2]University of Duisburg-Essen, Duisburg, Germany — [3]TH Wildau, Wildau, Germany — [4]FHI Berlin, Berlin, Germany

The analysis of magnetization dynamics on ultrafast timescales provides insight into microscopic interactions of magnetic moments with the charge and lattice degrees of freedom in solids. Here we analyze the finite size effect of ferromagnets on ultrafast timescales for $[Fe/MgO]_n$ heterostructures. Using femtosecond time-resolved XMCD, measured at the Femtoslicing facility, BESSY II, we observe an increasing laser-induced demagnetization at time delays > 0.5ps as the Fe layers get thinner, and it can be clearly distinguished from the primary ultrafast demagnetization occurring at < 0.5ps. Atomistic spin simulations are used to investigate the thickness dependence of the ultrafast magnetization dynamics in iron thin films, modeled using an extended Heisenberg-type Hamiltonian in the stochastic Landau-Lifshitz-Gilbert equation, coupled with the 2-temperature model. Comparing with our measurements, we conclude that finite size effects are the dominating factor for the different demagnetization rates due to a reduced spin-spin coordination at the interfaces.

MA 8.8 Mon 17:00 HSZ 04

A real-space tight-binding approach to ultrafast spin dynamics in inhomogeneous systems — •Franziska Ziolkowski, Oliver Busch, Ingrid Mertig, and Jürgen Henk — Martin Luther University Halle-Wittenberg, Halle, Germany

In laser-induced ultrafast spin dynamics a spin current is generated at a magnetic-nonmagnetic interface, whose orgin and properties are still under debate. To better understand the microscopic processes and the role of the interface we are developing the theoretical framework *evolve* [1].

In a real-space tight-binding model the electron system is optically excited by a femtosecond laser pulse and coupled to a bosonic bath. The time evolution of the density operator yields occupation numbers, demagnetization profiles as well as spin- and orbital-resolved occupation flows.

Our simulations confirm the importance of interfaces for ultrafast transport phenomena and demagnetization processes. We identify a reflow from Cu d orbitals across the interface into Co d orbitals as an important contribution to demagnetization. This refilling manifests itself as a minority-spin current proceeding several layers into the Cu region.

Moreover, we investigate the influence of pulse parameters such as polarization and photon energy.

[1] Töpler *et al* 2021 *New J. Phys.* **23** 033042

MA 8.9 Mon 17:15 HSZ 04

MEASURING THE SPIN-FLIP SCATTERING RATES IN THE DEMAGNETIZATION TRANSIENT STATE OF FERROMAGNETS — •Régis Decker[1], Artur Born[1,2], Kari Ruotsalainen[1], Karl Bauer[1], Robby Büchner[1,2], Robert Haverkamp[1,2], Annette Pietzsch[1], and Alexander Föhlisch[1,2] — [1]Institute Methods and Instrumentation for Synchrotron Radiation Research PS-ISRR, Helmholtz-Zentrum Berlin für Materialien und Energie Albert-Einstein-Strasse 15, 12489, Berlin, Germany. — [2]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Strasse 24-25, 14476, Potsdam, Germany

In crystalline ferromagnets, one of the main microscopic mechanisms of spin relaxation is the electron-phonon driven (Elliott-Yafet) spin-flip scattering. To deduce the spin-flip scattering rate, we exploit the stringent atomic symmetry selection rules of X-ray Emission Spectroscopy (XES) and observe the quantifiable change in the decay peak intensities in static XES spectra when changing the temperature, *i.e.* the phonon population. We deduce the temperature-dependent spin-flip scattering rate for Ni [1]. In FeNi alloys, we evidence a thresholding the Elliott-Yafet mechanism linked to the intra- and intersublattice exchange energies [2]. In Gd, we show an Elliott-Yafet mechanism for the itinerant 5d electrons and its absence for the localized 4f electrons [3].

[1] R. Decker *et al.*, Sci. Rep. **9**, 8977 (2019). [2] A. Born *et al.*, Sci. Rep. **11**, 1883 (2021). [3] R. Decker *et al.*, Appl. Phys. Lett. **119**, 152403 (2021).

MA 8.10 Mon 17:30 HSZ 04

Electron-magnon interactions and Elliot-Yafet Spin Flips in a Two Band Stoner Model — •Felix Dusabirane, Kai Leckron, Bärbel Rethfeld, and Hans Christian Schneider — Physics Department & Research Center OPTIMAS, RPTU Kaiserslautern, Germany

We study electronic scattering dynamics in ferromagnets due to electron-magnon and electron-electron scattering. We also include an electron-electron spin-flip process, i.e., an electronic Elliott-Yafet mechanism and study the dynamics due to the interplay of the different scattering processes on the magnetization on ultrafast timescales. For the ferromagnetic band structure, we employ a model system consisting of two Stoner-exchange split bands and electron-magnon interaction, as can be obtained using a Heisenberg model where magnons (and electrons) are treated as bosons (and fermions). Electron-electron and electron-magnon scattering dynamics are studied with Boltzmann scattering integrals. We show that the spin-flip electron-electron scattering together with electron-magnon scattering generates non-equilibrium magnons, leading to a pronounced magnetization change that is mostly due to magnon generation and only to a very limited extent to a change in the spin polarization of the electrons. The effect of electron spin-flips and time dependent spin splitting will also be discussed.

MA 8.11 Mon 17:45 HSZ 04

Nonequilibrium Magnons from Hot Electrons in Antiferromagnetic Systems — Marion Barbeau[1], Mikhail Titov[2], Mikhail Katsnelson[2], and •Alireza Qaiumzadeh[1] — [1]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [2]Radboud University, Institute for Molecules and Materials, 6525 AJ Nijmegen, The Netherlands

We describe a *nonthermal* magnon activation mechanism in antiferromagnetic (AFM) systems via locally equilibrated *spin-unpolarized* hot electrons excited by an ultrafast intense laser pulse. We employ a quantum kinetic equation that takes into account a direct electron-magnon scattering channel in either bulk AFM metal or at the interface of the AFM/normal-metal heterostructure. The mechanism is responsible for the nonequilibrium population of AFM magnon modes on a subnanosecond timescale, which are formed shortly after the local thermalization of hot electrons by Coulomb interactions. Nonequilibrium magnon populations can be additionally manipulated by applying an external magnetic field. Our work paves the way toward spin dynamics control in AFM systems via the ultrafast manipulation of out-of-equilibrium magnon excitations [1].

[1] M. M. S. Barbeau, M. Titov, M. I. Katsnelson, A. Qaiumzadeh, arXiv:2209.03469v1

MA 9: Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions

Time: Monday 15:00–17:45 Location: HSZ 401

MA 9.1 Mon 15:00 HSZ 401

Spin functional renormalization group for dimerized quantum spin systems — Andreas Rückriegel, •Jonas Arnold, Raphael Goll, and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Straße 1, 60438 Frankfurt, Germany

We investigate dimerized quantum spin systems using the spin functional renormalization group approach proposed by Krieg and Kopietz [Phys. Rev. B **99**, 060403(R) (2019)] which directly focuses on the physical spin correlation functions and avoids the representation of the spins in terms of fermionic or bosonic auxiliary operators. Starting from decoupled dimers as initial condition for the renormalization group flow equations, we obtain the spectrum of the triplet excitations as well as the magnetization in the quantum paramagnetic, ferromagnetic, and thermally disordered phases at all temperatures. Moreover, we compute the full phase diagram of a weakly coupled dimerized spin system in three dimensions, including the correct mean field critical exponents at the two quantum critical points.

MA 9.2 Mon 15:15 HSZ 401

Magnetic correlations in the presence of disorder in the Hubbard model — •Fabio Pablo Miguel Méndez-Córdoba[1,2,3], Joseph Tindall[4], Dieter Jaksch[2,5], and Frank Schlawin[2,3,6] — [1]Departamento de Física, Universidad de Los Andes, A.A. 4976, Bogotá, Colombia — [2]Universität Hamburg, Luruper Chaussee 149, Gebäude 69, D-22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg D-22761, Germany — [4]Center for Computational Quantum Physics, Flatiron Institute, 162 5th Avenue, New York, NY 10010 — [5]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [6]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany

By selectively modifying hopping integrals in the triangular Hubbard model at half filling [1], we show that it is possible to change the ground state's spin angular momentum magnetization. We further demonstrate that this change does not appear in the corresponding effective Heisenberg model. The latter does not predict any magnetic coherence between distant sites [2]. Instead, higher-order interactions are required to anticipate the symmetry breaking that leads to the lifting of the degeneracy present in the Heisenberg model. Our results can be understood as an extension of Lieb's theorem to non-bipartite lattices [3].

[1] J. Tindall, et al., Phys. Rev. Lett. 125, 137001 (2020). [2] J. Strecka, et al., Phys. Rev. B 105, 064420 (2022). [3] E. H. Lieb, Phys. Rev. Lett. 62, 1201 (1989).

MA 9.3 Mon 15:30 HSZ 401

Subsequent Mott transitions and magnetic ground state in NiS_2 — •Jonas A. Krieger[1], Fabio Orlandi[2], Mikel I. Iñurrieta[3], Iñigo Robredo[3], Zaher Salman[4], Niels B. M. Schröter[1], Maia Garcia-Vergniory[3], Stuart S. P. Parkin[1], and Leslie Schoop[5] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Rutherford Appleton Laboratory, Didcot, UK — [3]Donostia International Physics Center, San Sebastián, Spain — [4]Paul Scherrer Institute, Villigen, Switzerland — [5]Princeton University, Princeton, USA

We present muon spin spectroscopy (μSR) measurements on the antiferromagnetic Mott insulator NiS_2. This compound features two subsequent magnetic phase transitions around 38.9K and 29K associated with the opening of a Mott gap. From the zero field and rotation dependence of transverse field μSR spectra we confirm the magnetic space group 205.33 in the 38.9K to 29K phase, determined from neutron diffraction [1]. We refine the muon stopping sites by using ab-initio density functional theory (DFT) and show that the resulting 8c and 24d muon sites can fully explain the observed μSR precession frequencies. A disproportionate temperature evolution of the two frequencies associated with these sites points to the presence of a strong temperature dependence in the muon hyperfine coupling strength due to concomitant changes in the electronic structure. We then use the number of μSR frequencies in combination with complementary neutron diffraction results to identify the magnetic ground state.

[1] S. Yano, et al., Phys. Rev. B 93, 024409 (2016)

MA 9.4 Mon 15:45 HSZ 401

Magnetocrystalline anisotropies and quantum phase transitions in the cubic chiral magnets $Mn_{1-x}Fe_xSi$ and $Mn_{1-x}Co_xSi$ — •Vivek Kumar, Andreas Bauer, Marc Andreas Wilde, and Christian Pfleiderer — Physik-Department, Technische Universität München, D-85748 Garching, Germany

In the archetypical cubic chiral magnet MnSi, an extended regime of topological non-Fermi liquid behavior emerges without quantum criticality as magnetic order is suppressed by means of hydrostatic pressure [1]. Substitutional doping with iron or cobalt also results in the suppression of magnetic order, where quantum critical behavior is masked by the influence of disorder [2]. Recent small-angle neutron scattering studies suggested that in this context magnetocrystalline anisotropies may subtly but decisively influence the magnetic textures, however, no quantitative information was available [3]. Here, we report a study of a series of single crystals of $Mn_{1-x}Fe_xSi$ and $Mn_{1-x}Co_xSi$ by means of cantilever torque magnetometry. An analytic description that takes into account the tetrahedral point group of the cubic chiral magnets allows us to quantitatively infer anisotropy constants up to sixth-order in spin-orbit coupling and discuss their evolution as a function of temperature, magnetic field, and dopant concentration x.

[1] Pfleiderer *et al.*, Science **316**, 1871 (2007).
[2] Bauer *et al.*, Phys. Rev. B **82**, 064409 (2010).
[3] Kindervater *et al.*, Phys. Rev. B **101**, 104406 (2020).

15 min. break

MA 9.5 Mon 16:15 HSZ 401

Investigating the CMR Effect in $EuCd_2P_2$ by Means of Nonlinear Transport and Fluctuation Spectroscopy — •Marvin Kopp[1], Charu Garg[1], Sarah Krebber[1], Kristin Kliemt[1], Cornelius Krellner[1], Sudhaman Balguri[2], Fazel Tafti[2], and Jens Müller[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (Main), Germany — [2]Departments of Physics, Boston College, USA

The colossal magnetoresistance (CMR) effect has inspired extensive studies for decades and is still the subject of intense research due to its central place in the physics of correlated electron systems as well as its potential relevance for applications. Unlike the prototypical CMR compounds based on mixed valence and double exchange in manganites or a structural Jahn-Teller distortion and ferromagnetic ordering, we focus on $EuCd_2P_2$, that exhibits a strikingly large (10^4 %) negative MR significantly above its antiferromagnetic ordering temperature $T_N = 11$ K. Initial reports suggest that strong magnetic fluctuations within the layered structure could be responsible for the drastic change of resistance in the magnetic field [1]. In this work, we aim to investigate these fluctuations using higher harmonic resistance and resistance fluctuation (noise) spectroscopy. Higher harmonic measurements are sensitive to the small changes in magneto-electric coupling caused by the postulated forming of magnetic clusters (polarons), often hidden in standard resistance measurements. The dynamics of these magnetic clusters is studied using resistance noise spectroscopy as a function of temperature and magnetic field. [1] Adv. Mat., 2021, 33, 2005755.

MA 9.6 Mon 16:30 HSZ 401

Investigating the electronic charge and magnetic spin dynamics in the ferromagnetic semiconductor $HgCr_2Se_4$ using resistance fluctuation (noise) spectroscopy — •Charu Garg[1], Zhilin Li[2], Youguo Shi[2], and Jens Müller[1] — [1]Institute of Physics, Goethe University, 60438 Frankfurt (M), Germany — [2]Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190

The n-type $HgCr_2Se_4$ has been reported to exhibit a pronounced semiconductor-to-metal transition below and a CMR effect at the ferromagnetic transition at $T_C = 107$ K. Our recent study of charge carrier dynamics [Phys. Rev B 105, 064404 (2022)] suggests isolated magnetic polarons forming at $T > 2T_C$ which coalesce at T_C. In this talk, we discuss new results highlighting the strong correlation between the magnetic and electronic degrees of freedom that can lead to complex exchange pathways. Likely due to competing AF and FM interactions, we observe a distinctly slow decrease in resistance below the CMR transition. The striking dynamics of a distinct two-level fluctuations superimposed on 1/f-type noise corroborates a slowing down of charge carrier and/or magnetic dynamics. Further, below 20 K, a strong upturn in resistance and simultaneously in resistance noise down to 500 mK is observed and is speculated to be linked to the emergence of spiral type magnetic order. Our results demonstrate that the presence of pronounced electron-spin correlations plays a key role in the unconventional temperature dependence of resistance and CMR effect in this spinel.

MA 9.7 Mon 16:45 HSZ 401

Field-induced magnetic excitations in phases II and II′ of $Ce_3Pd_{20}Ge_6$ — •Federico Mazza[1], Jakob Lass[2], Daniel Mazzone[2], Stewart Ross[3], Eun Sang Choi[4], Martin Nikolo[5], Xinlin Yan[1], Andrey Prokofiev[1], Silke Paschen[1], and Dmytro S. Inosov[6] — [1]TU Wien, Austria — [2]PSI, Villigen, Switzerland — [3]ISIS, Didcot, UK — [4]Florida State University, Tallahassee, USA — [5]St. Louis University, USA — [6]TU Dresden, Germany

$Ce_3Pd_{20}Ge_6$ is known for its unique quantum phase transitions between antiferromagnetic ordering phase III and ferroquadrupolar phases II and II′. Using torque magnetometry at subkelvin temperatures, we were able to map the phase diagram in field and momentum space, here we find the crossover between phases III-II′ at 1.5 T and II′-II at 8 T. In addition, with inelastic neutron scattering we investigate dispersive collective excitations with a strong magnetic field dependence for $\mathbf{B} \parallel (110)$, revealing a magnon soft mode (Goldstone mode) at (001) for phase III and (111) for phases II and II′. At 4 meV we discover the presence of two (CEF) excitations exhibiting a weak dispersion best seen in the $(HH1)$ direction. They are degenerate in the absence of magnetic field but split progressively as the field is increased.

MA 9.8 Mon 17:00 HSZ 401

Magnetoelastic coupling in the skyrmion lattice magnet $GdRu_2Si_2$ — •Lukas Gries[1], Daniel Mayoh[2], George Wood[2], Geetha Balakrishnan[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, University of Warwick, United Kingdom

We present high-resolution thermal expansion and magnetostriction studies on the centrosymmetric skyrmion-hosting tetragonal magnet $GdRu_2Si_2$ in high magnetic fields up to 15 T. Our data show magnetoelastic coupling associated with the onset of long-range antiferromagnet order in form of pronounced anomalies in thermal expansion and magnetostriction. We extract the uniaxial pressure dependencies of the different phase boundaries and discuss them in terms of spin-lattice coupling. Our data suggest additional phases in magnetic field and allow us to complement the previously published magnetic phase diagram.

MA 9.9 Mon 17:15 HSZ 401

Charge dynamics of heavy fermions near their quantum critical point — •Renjith Mathew Roy[1], Run Yang[1], Sooheyon shin[2], Seulki Roh[1], and Martin Dressel[1] — [1]1. Physikslisches Instiut, Universität stuttgart, Germany — [2]Laboratory for Multiscale Materials Experiments, Paul Scherrer Institut, Switzerland

Using infrared spectroscopy, we investigate the evolution of hybridization strength between the localized magnetic moments and itinerant electrons in heavy fermionic compound CeRh(In1-xSnx)5, with three different Sn concentrations, Sn 4.4%, Sn 6.9%, and 9.8% respectively. CeRhIn5 has an antiferromagnetic ground state, which is suppressed with Sn doping revealing a quantum-critical region. From our optical conductivity result, we report an enhancement of hybridization strength with increasing Sn concentration, and the observation of a non-Fermi liquid behaviour near the quantum critical point. The phase characterization was performed by magnetic susceptibility and resistivity measurements, which also support the non-Fermi liquid behavior observed near the quantum critical point.

MA 9.10 Mon 17:30 HSZ 401

Local structure of disordered $Fe_{60}V_{40}$ and the impact on its magnetism — •Simon Rauls[1], Benedikt Eggert[1], Shadab Anwar[2], Damian Günzing[1], Philipp Klassen[1], Tom Helbig[1], Rantej Bali[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Helmholtz-Zentrum Dresden-Rossendorf

Control of the structural order and nearest-neighbour interactions can provide a path to modify application relevant magnetic properties, such as the Gilbert damping. The binary alloy $Fe_{60}V_{40}$ shows an amorphous to polycrystalline phase transition, which can be triggered by annealing or ion irradiation. This phase transition also is a transition from a paramagnetic phase towards a ferromagnetic phase with very low Gilbert damping of ∼0.002 [1], which makes the material a promising candidate for the fabrication of embedded magnetic nanostructures in a single irradiation step. We want to highlight the results of our structural and magnetic investigations on $Fe_{60}V_{40}$ thin films, using EXAFS, magnetometry and Mössbauer spectroscopy, in order to understand the interconnection between the evolving ferromagnetism and nearest-neighbour interactions along the ion-irradiation induced phase transition.

We acknowledge financial support from the DFG through project no. 322462997 and DESY for beamtime allocation at beamline P65.

[1] S. Anwar et al. *ACS Appl. Electron. Mater.* 2022, **4**, 8 3860-3869

MA 10: Topological Insulators (joint session MA/TT)

Time: Monday 15:00–17:15 Location: HSZ 403

MA 10.1 Mon 15:00 HSZ 403

Benchmark study of symmetry-adapted ML-DFT models for magnetically doped topological insulators — •Johannes Wasmer[1], Rubel Mozumder[1], Philipp Rüssmann[1,2], Ira Assent[1,3], and Stefan Blügel[1] — [1]Forschungszentrum Jülich, Germany — [2]University of Würzburg, Germany — [3]Aarhus University, Denmark

We present a benchmark study of surrogate models for impurities embedded into crystalline solids. Using the Korringa-Kohn-Rostoker Green Function method [1], we have built databases of several thousand calculations of single impurities (monomers) embedded into different elemental crystals, as well as magnetic transition metal impurity dimers embedded in the topological insulator Bi_2Te_3. We predict the converged monomer impurity electron potential and the isotropic exchange interaction of the impurity dimer in the classical Heisenberg model. From these surrogates, we intend to build transferable models for larger systems in the future, which will accelerate the convergence of our DFT codes. The study compares various recent E(3)-equivariant models such as ACE and MACE [2] in terms of performance and reproducible end-to-end workflows.

[1] P. Rüßmann et al., npj Comput Mater 7, 13 (2021)
[2] I. Batatia et al., arXiv:2206.07697 (2022)

MA 10.2 Mon 15:15 HSZ 403

High thorughput magnetic topological materials search II — •Iñigo Robredo[1,2], Yuanfeng Xu[3,4], Andrei Bernevig[2,3], Claudia Felser[1], Nicolas Regnault[3,6], Luis Elcoro[5], and Maia G. Vergniory[1,2] — [1]MPI CPFS Dresden — [2]DIPC — [3]Princeton University — [4]Zhejiang University — [5]Basque Country University — [6]Sorbonne Université

The development of topological quantum chemistry has proven to be a game changing tool for predicting topological phases in realistic materials, both non-magnetic and magnetic. Building on the work of previous studies, in this work we expand the family of magnetic insulators and semimetals with non-trivial topological properties. We analyzed 408 magnetic structures from the Bilbao Crystallographic Server magnetic database, whose crystal and magnetic structures have been experimentally reported. To take into account the localized nature of magnetic elements, we perform electronic structure calculations and topological diagnosis as a function of the Hubabrd U parameter. This results in a topological phase iagram for each material as a function of the Hubbard interaction potential. We provide full details of the materials, which can be readily grown to explore their new topological phenomena.

MA 10.3 Mon 15:30 HSZ 403

Manipulating topological feature of massive Dirac particle with scalar potential — •Sumit Ghosh[1,2], Yuriy Mokrousov[1,2], and Stefan Blügel[1] — [1]PGI-1, Forschungszentrum Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany

Topology is one of the central aspect of modern spintronics. Different physical observables as well as transport properties that originates from the nontrivial topology of the system shows significant robustness against different external perturbation. Manipulating the topology of a system on the other hand is a highly non-trivial task since it requires tuning the internal degrees of freedom. In this presentation we are going to present an intrinsic mechanism to manipulate the topological feature and associated transport properties by using scalar potential. We systematically demonstrate how a scalar potential can invert the mass term of a massive Dirac particle which subsequently leads to the change of the topological index. We further demonstrate how this mechanism can be exploited to control the formation of edge states which can control the transport properties. This study thus provides a better understanding of the origin of the topological properties as well as a simple way to manipulate them. [https://arxiv.org/abs/2204.06412]

MA 10.4 Mon 15:45 HSZ 403

Mapping out the topological phase diagram of FeSn — Soumya Sankar[1], Ruizi Liu[2], Xuejian Gao[1], Qifang Li[3,4], JiaChang Zheng[1], Caiyun Chen[1], Chengping Zhang[1], Kun Qiang[2], Zi Yang Meng[3,4], Kam Tuen Law[1], Qiming Shao[1,2], and •Berthold Jäck[1] — [1]HKUST, Clear Water Bay, Kowloon, Hong Kong SAR — [2]HKUST, Department of Computer Science and Electrical Enginerring, Clear Water Bay, Kowloon, Hong Kong SAR — [3]Hong Kong University, Department of Physics, Pokfulam Road, Hong Kong SAR — [4]University of Tokyo, Department of Physics, Hongo, Bunkyo City, Tokyo

Metallic kagome magnets exhibit a flat band and a Dirac point in their electronic structure and long-range magnetic order. The combination of these properties creates favourable conditions to search for strongly correlated and topological electronic states. The near-ideal kagome band structure of the inter metallic kagome series X1Y1 offers opportunities to study the interplay between strong electronic correlations, topology, and magnetism.

We have used molecular beam epitaxy and electronic transport measurements to study the interplay of magnetism and band topology in thin films of antiferromagnetic FeSn. We will present results from a magnetic field and temperature dependent study of the anomalous Hall effect. Combining these measurements with magnetic Monte-Carlo simulations and theoretical model calculations, we map out the topological phase diagram of FeSn over a large temperature range.

We acknowledge support by the GRC, and the Croucher Foundation.

15 min. break

MA 10.5 Mon 16:15 HSZ 403

Investigation of the magnetic topological insulator family (MnPn2Te4) (Pn2Te3) n, (Pn=Bi, Sb) by μSR and NMR — •Manaswini Sahoo[1,2], Anna Isaeva[1], Bernd Büchner[1], and Roberto De Renzi[2] — [1]Leibniz IFW Dresden, Dresden, Germany — [2]University of Parma,Parma, Italy

Time-reversal symmetry breaking in a topological insulator (TI) opens a surface gap and distinguishes chiral quantum states that could eventually be exploited in electrically controlled spintronic devices. The recent discovery of layered van der Waals materials opens a new approach to achieve this.(MnBi2Te4) (Bi2Te3) n is one of the first such examples, where the increasing number n of TI layers controls the magnetic dimensionality of the material. These compounds do display the quantum anomalous Hall effect, where spontaneous magnetization and spin-orbit coupling lead to a topologically non-trivial electronic structure. In the case of (MnBi2Te4) (Bi2Te3) n, Zero Field μSR shows more than one internal field at the muon site with the majority one decreasing in value when n is increased. The muon spin precessions display very fast relaxations of static inhomogeneous nature. Whereas in the sister compound MnSb2Te4, Zero Field μSR shows a broader distribution of magnetic field at the muon due to larger intermixing between Mn/Sb in the sample. Importantly, the weak Transverse Field shows a sharp magnetic transition at the same Tc, with a clear relaxation peak due to critical fluctuations, taking place in the whole volume of the material. This local information from μSR together with NMR is crucial to correctly interpret macroscopic magnetization data.

MA 10.6 Mon 16:30 HSZ 403

Magnetic dilution effect and topological phase transitions in antiferromagnet $Mn_{1-x}Pb_xBi_2Te_4$ — •Yueh-Ting Yao[1], Tiema Qian[2], Tay-Rong Chang[1,3,4], and Ni Ni[2] — [1]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan — [2]Department of Physics and Astronomy and California NanoSystems Institute, University of California, Los Angeles, California 90095, USA — [3]Center for Quantum Frontiers of Research and Technology (QFort), Tainan 701, Taiwan — [4]Physics Division, National Center for Theoretical Sciences, Taipei 10617, Taiwan

The interplay between magnetism and topology have taken the central stage of modern condensed matter physics in the past three years. The fine control of magnetism and topology in a magnetic topological insulator is crucial for realizing various novel magnetic topological phases, such as axion insulator, magnetic Weyl semimetals, etc. In this work, we investigate the evolution of magnetism and band topology in $Mn_{1-x}Pb_xBi_2Te_4$ via angle resolved photoemission spectroscopy (ARPES), first-principles calculations, and electronic transports. We present the comprehensive phase diagram by controlling Pb content and magnetism in this alloy system. Moreover, we provide the first topological crystalline insulator with non-trivial glide mirror Chern number in MnBi2Te4-family materials, which is protected by non-symmorphic symmetry arise from antiferromagnetic (AFM) configuration. Our work provides a fruitful platform with continuously tunable magnetism and topology for investigating emergent phenomena and pave a way towards potential new applications of nanoelectronics.

MA 10.7 Mon 16:45 HSZ 403

Thermal Hall Effect of Magnon-Phonon Hybrid Quasiparticles in a Fluctuating Heisenberg-Kitaev Antiferromagnet — •Robin R. Neumann[1], Alexander Mook[2], Jürgen Henk[1], and Ingrid Mertig[1] — [1]Martin Luther University Halle-Wittenberg, Halle (Saale), Germany — [2]Johannes Gutenberg University, Mainz, Germany

Magnons, the quantized excitations of localized spins, and phonons, the quantized excitations of the lattice, are two types of quasiparticles that are responsible for heat transport in magnetic insulators. However, phonons by themselves do not contribute to the *transverse* heat current induced by a temperature gradient, i.e., the thermal Hall effect (THE). Magnons, on the other hand, may exhibit a Berry curvature, a magnetic field in reciprocal space, that leads to an intrinsic THE.

In this talk, I address the THE in a Heisenberg-Kitaev antiferromagnet subjected to a magnetic field. The applied field drives the system from a zigzag antiferromagnetic to a spin-flop state. The magnon-driven THE indicates the magnetic phase transition by a sign change at the critical field. Furthermore, when the magnetoelastic interaction is considered, the phonon and magnon bands hybridize and additional Berry curvature at the avoided crossings emerge. Depending on the strength of the spin-phonon coupling, this may lead to an overall reversal of the THE while the field-induced sign change at the critical field remains mostly robust. These results showcase that magnon-phonon hybridization can be pivotal for the interpretation of transport experiments.

MA 10.8 Mon 17:00 HSZ 403

Limitations of the Bulk-Boundary Correspondence in Topological Magnon Insulators due to Magnon-Magnon Interactions — •Jonas Habel[1], Johannes Knolle[1], Alexander Mook[2], and Josef Willsher[1] — [1]Technical University of Munich, Germany (Theory of Quantum Matter and Nanophysics) — [2]Johannes Gutenberg University Mainz, Germany

Magnon excitations in ordered quantum magnets can exhibit topological band structures characterized by non-zero Chern numbers. Such magnonic Chern insulators are widely believed to host protected chiral edge modes due to the bulk-boundary correspondence, in analogy to electronic Chern insulators. However, in contrast to electrons, magnons are bosons and can thus be subject to exotic number-nonconserving many-body interactions, enabling potentially strong spontaneous decays at zero temperature.

To assess their effect on the chiral edge magnons, we study a topological honeycomb-lattice ferromagnet with Dzyaloshinskii-Moriya interactions using many-body perturbation theory. We discover that non-harmonic terms of the spin-wave expansion may lead to severe lifetime reduction of edge modes and their delocalisation into the bulk. For sufficiently strong interactions, the spectral weight of the chiral edge magnons vanishes entirely. These findings indicate that topological magnon bands within the harmonic framework do not necessarily give rise to protected edge modes in the full spin theory, suggesting limitations of the bulk-boundary correspondence in this case.

MA 11: Non-Skyrmionic Magnetic Textures I

Time: Monday 15:00–16:45 Location: POT 6

MA 11.1 Mon 15:00 POT 6

Topological defects in a multiferroic antiferromagnet — •Aurore Finco[1], Angela Haykal[1], Stéphane Fusil[2], Pawan Kumar[1], Pauline Dufour[2], Anne Forget[3], Dorothée Colson[3], Jean-Yves Chauleau[3], Michel Viret[3], Nicolas Jaouen[4], Vincent Garcia[2], and Vincent Jacques[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Unité Mixte de Physique, CNRS, Thales, Université Paris-Saclay, Palaiseau, France — [3]SPEC, CEA, CNRS, Université Paris-Saclay, Gif sur Yvette, France — [4]Synchrotron SOLEIL, Gif-sur-Yvette, France

We report on the formation of topological defects emerging from the cycloidal order at the surface of bulk $BiFeO_3$ crystals [1]. Combining reciprocal and real-space magnetic imaging techniques, we first observe, in a single ferroelectric domain, the coexistence of regions in which the antiferromagnetic cycloid propagates along different wave vectors. We then show that the direction of these wave vectors is not strictly locked to the preferred crystallographic axes but rather rotates continuously. At the junctions between the magnetic domains, we observe topological line defects identical to those found in a broad variety of lamellar physical systems with rotational symmetries. Our work establishes the presence of these magnetic objects at room temperature in the multiferroic antiferromagnet $BiFeO_3$, offering new opportunities in terms of robustness and electrical control towards their use in spintronic devices.

[1] Finco et al, *Phys. Rev. Lett.* 128, 187201 (2022)

MA 11.2 Mon 15:15 POT 6

Domain structures of stressed free-hanging magnetic thin films — Dhavalkumar Mungpara[1], •Alexander Schwarz[1], Federico Maspero[2], Riccardo Bertacco[2], Nicola Manca[3], Leonèlio Cichetto Jr.[3], and Luca Pellegrino[3] — [1]INF, University of Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]CNR-IFN, Piazza Leonardo da Vinci 32, 20133 Milano, Italy — [3]CNR-SPIN Corso F. M. Perrone 24, 16152 Genova, Italy

This work has been conducted as part of the OXiNEMS project, which aims to realize a miniaturized all-oxide hybrid sensor able to detect magnetic fields in the fT-regime. Our envisaged design encompasses a superconducting pick-up loop with a constriction and a magnetically sensitive resonator placed directly above.

To achieve a high sensitivity, the resonator must have a high Q-value, which is accomplished by a large in-plane stress. To obtain magnetic sensitivity, the resonator itself can be magnetic, or a magnetic thin film element is grown on top of a non-magnetic resonator. Of course, the magnetic sensitivity of the whole device depends on the magnetic properties of the resonator. Therefore, we investigated the domain structure of two promising resonator candidates using magnetic force microscopy: 100 nm thick Co rectangles on non-magnetic silicon nitride trampoline resonators and 100 nm thick magnetic $La_{0.7}Sr_{0.3}MnO_3$ trampoline resonators.

The OXiNEMS project (www.oxinems.eu) has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 828784.

MA 11.3 Mon 15:30 POT 6

Stability and dynamics of SO(3) solitons in magnetically frustrated systems — •Ricardo Zarzuela — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

In recent years frustrated magnets have resurged in condensed matter due to their striking spin transport properties [1,2] and ability to host three-dimensional magnetic solitons, such as Shankar skyrmions [3] or Anderson-Toulouse vortices [4]. The latter emerge in the corresponding SO(3)-order parameter (describing the spin-spin correlation of the system), have potential use in topological computing and high-density memory storage, and coexist with those conventional magnetic solitons encoded in the total magnetization field (e.g., domain walls and baby skyrmions). We discuss the stability of these SO(3) solitons for several phenomenological models for a magnetically frustrated platform and, within a collective variable approach, we also explore their dynamics in the presence of spin-transfer torques and topological defects.

[1] N.L. Nair, E. Maniv, C. John, S. Doyle, J. Orenstein, and J.G. Analytis. Nat. Mater. 19, 153 (2020).
[2] R. Zarzuela and J. Sinova, arXiv:2112.06680 (2022).
[3] R. Shankar, J. Physique 38, 1405 (1977).
[4] P.W. Anderson and G. Toulouse, Phys. Rev. Lett. 38, 508 (1976).

15 min. break

MA 11.4 Mon 16:00 POT 6

Interaction of antiferromagnetic domain walls with crystal defects — •Oleksandr V. Pylypovskyi[1,2], Artem V. Tomilo[1], Natascha Hedrich[3], Kai Wagner[3], Brenan J. Shields[3], Tobias Kosub[1], René Hübner[1], Jürgen Fassbender[1], Denis D. Sheka[4], Patrick Maletinsky[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]Kyiv Academic University, 03142 Kyiv, Ukraine — [3]University of Basel, Basel CH-4056, Switzerland — [4]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Understanding behavior of magnetic texture in antiferromagnetic nanostructures and thin films is crucial for the design of novel magnetic data storage and logic devices. Here, we derive the boundary conditions for the Néel vector in a two-sublattice antiferromagnet (AFM) and apply them to describe the shape of the domain walls [1,2] and skyrmions [2] in confined samples. In general, the surface of a 3D domain wall behaves as an elastic ribbon which bends in response on the topographic features of the single crystal Cr_2O_3 [1]. In presence of the Dzyaloshinskii-Moriya interaction, topologically non-trivial AFM textures possess broadening near the surface. In thin films, the sample's granularity becomes crucial. We present a model of a granular AFM and, by comparison with Nitrogen Vacancy magnetometry of 200-nm-thick Cr_2O_3 films, estimate the inter-grain exchange strength. The grain boundaries act as strong pinning sites for the AFM texture. [1] N. Hedrich et al., Nat. Phys. 17, 574 (2021); [2] O. Pylypovskyi et al., Phys. Rev. B 103, 134413 (2021).

MA 11.5 Mon 16:15 POT 6

Evaluation of phase images obtained by electron holography for three-dimensional spin-textures — •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

Three-dimensional (3D) spin-textures, similarly to their 2D counterpart (skyrmions), are attracting widespread interest, especially because of their potential application as magnetic bits for energy-efficient storage devices. Thereby, a major challenge is their identification. Here we focus on electron holography, where phase images are reconstructed in order to recognize 3D spin-textures. The phase image consists of an electronic and a magnetic contribution, with the latter being assumed to emerge from the stray field, and thus should vanish for antiferromagnets, while the former is conjectured to be inert to the magnetic texture. Here we demonstrate that the electronic phase image carries non-trivial magnetic information induced by spin-mixing and spin-orbit mechanisms. We calculate and compare systematically the strength of both electronic and magnetic phase images employing the optimized forward model [1] and a tight-binding scheme combined with multiple-scattering theory. We explore the impact of spin-orbit interaction, exchange splitting and hopping.

[1] J. Caron, Model-Based Reconstruction of Magnetisation Distributions in Nanostructures from Electron Optical Phase Images, PhD thesis, RWTH Aachen Uni. (2017).

MA 11.6 Mon 16:30 POT 6

X-ray holographic imaging of magnetic surface spirals in FeGe lamellae — •Luke A. Turnbull[1], Matthew T. Littlehales[1], Murray N. Wilson[1], Max T. Birch[2], Horia Popescu[3], Nicolas Jaouen[3], Joel Verezhak[4], Geetha Balakrishnan[4], and Peter D. Hatton[1] — [1]Department of Physics, Durham University, Durham, DH1 3LE, UK — [2]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [3]Synchrotron SOLEIL, Saint Aubin, BP 48 91192 Gif-sur-Yvette, France — [4]Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

Isotropic helimagnets are known to host a diverse range of chiral magnetic states. In 2016, F.N. Rybakov et al. theorized the presence of a surface-pinned stacked spin spiral phase [F.N. Rybakov et al., 2016 New J. Phys. 18 045002], which had yet to be observed experimentally. The phase is characterized by surface spiral periods exceeding the host material's fundamental winding period, L. In this talk we present experimental evidence for the observation of this state in lamellae of FeGe using resonant x-ray holographic imaging data and micromagnetic simulations. We find images of FeGe lamellae, exceeding a critical thickness of 300 nm (4.3L), exhibit contrast modulations with a field-dependent periodicity of x<1.4L, consistent with theoretical predictions of the stacked spiral state. The identification of this spiral state carries significant implications for the stability of other coexisting spin textures in chiral helimagnets, and indicates the utility in considering magnetic systems in three-dimensions.

MA 12: Skyrmions II

Time: Tuesday 9:30–11:30 Location: HSZ 02

MA 12.1 Tue 9:30 HSZ 02

Coexistence of distinct skyrmionic 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

The field of skyrmionics has attracted great research interest, as skyrmions – whirl-like nano-objects – are very stable which makes them potential carriers of information in future data storage devices. However, their integer topological charge causes two shortcomings of skyrmion-based racetrack storages: The skyrmions do not move parallel to a current and multiple skyrmions attract and repell each other.

In this talk, I present several alternative nano-objects that go beyond conventional skyrmions [1]. We discuss via simulations, Lorentz transmission electron microscopy measurements [2,3] and Hall transport measurements [4] that skyrmions, antiskyrmion and topologically trivial bubbles [5] can coexist. They can even appear fractionally near the sample's edges [6]. The interplay of Dzyaloshinskii-Moriya and dipolar interactions leads to interesting coexistence and deformation phenomena that may even be utilized for neuromorphic applications.

[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) [7] Ribeiro de Assis, Mertig, BG arXiv: 2209.11017

MA 12.2 Tue 9:45 HSZ 02

Magnetic Néel Domain Walls and Skyrmions in La0.7Sr0.3Mn1-xRuxO3 Multilayers — •Arsha Thampi[1], Jörg Schöpf[2], Daniel Wolf[1], Ionela Lindfors-Vrejoiu[2], and Axel Lubk[1,3] — [1]Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]Physics Institute, University of Cologne, 50937 Cologne, Germany — [3]Institute of Solid State and Materials Physics, TU Dresden, 01069 Dresden, Germany

Magnetic domain walls (DWs) in ferromagnetic thin films exhibit a rich variety of configurations and corresponding dynamic properties depending on parameters like film thickness, defect density, magnetocrystalline anisotropy, exchange stiffness, and Dzyaloshinskii*Moriya interaction (DMI). Here, we study epitaxial ferromagnetic multilayer devices of La0.7Sr0.3Mn1-xRuxO3, consisting 8 nm thick manganite layers with varying Ru/Mn content, in order to engineer symmetric and antisymmetric exchange interaction and magnetic anisotropy across the multilayer stack. We particularly map the DW states as a function of temperature and external out-of-plane magnetic fields employing high-resolution magnetic imaging in the Transmission Electron Microscopy (TEM). Lorentz TEM and transport of intensity phase reconstruction is used to characterize the magnetic domains and DWs formed as a function of temperature and perpendicular magnetic field strength. High-resolution magnetic field mapping of La0.7Sr0.3Mn1-xRuxO3 multilayer system demonstrates the possibility to engineer chiral Néel domain walls and skyrmions.

MA 12.3 Tue 10:00 HSZ 02

In-situ correlation of the anomalous Hall effect with the occurrence of topological and non-topological magnetic phases in $Mn_{1.4}PtSn$ — •Darius Pohl[1], Andy Thomas[2], Sebastian Schneider[1], Dominik Krieger[3], Yejin Lee[2], Praveen Vir[4], Claudia Felser[4], Moritz Winter[1,4], and Bernd Rellinghaus[1] — [1]Dresden Center for Nanoanalysis (DCN), cfaed, TU Dresden, D-

01062 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research Dresden, D-01062 Dresden, Germany — [3]Institute of Solid State and Materials Physics, TU Dresden, D-01062 Dresden, Germany — [4]Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden, Germany

Topologically protected (anti-)skyrmions are potential future information carriers, since they can be electrically manipulated and detected, e.g., by measuring their Hall signature. Hall measurements are usually conducted on samples with different geometries as compared to those used for Lorentz TEM magnetic imaging. In magnetic phases which are strongly influenced by dipole-dipole interactions, such comparisons are problematic. We devised an experimental setup that bridges this gap and allows for the conduction of in-situ Hall measurements in a TEM. Besides proof-of-principle experiments on thin Ni films, our new setup allows us to follow in detail the field dependence of the Hall voltage while simultaneously monitoring the magnetic phases in $Mn_{1.4}PtSn$. This provides valuable insights into the existence and nature of an intensely debated electrical signature of skyrmionics structures. Financial support by DFG through SPP 2137 is gratefully acknowledged.

MA 12.4 Tue 10:15 HSZ 02

Room temperature stabilization of skyrmionic spin textures in synthetic antiferromagnets — •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 show 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), 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 in data storage devices [3]. Here, we investigate different, more exotic spin textures beyond skyrmions in a SAF consisting of CoFeB/Ir/CoFeB multilayers by using scanning electron microscopy with polarization analysis (SEMPA). The surface sensitivity of SEMPA is especially effective on SAFs enabling us to investigate the topological spin textures even in a fully compensated composition. We report merons and antimerons 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 of stabilization of 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 12.5 Tue 10:30 HSZ 02

Evidence for Chiral Soliton Lattice formation in the Antiskyrmion compound $Mn_{1.4}PtSn$ — •M. Winter[1,2,3], M. Rahn[4], D. Wolf[3], S. Schneider[2], M. Valvidares[5], C. Shekar[1], P. Vir[1], B. Achinuq[6], H. Popescu[7], T. Helm[8], G. Van der Laan[9], 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]HZDR,Dresden,Germany — [9]Diamond Light Source, Didcot, UK

The Antiskyrmion (aSks) compound $Mn_{1.4}PtSn$ has a rich magnetic phase diagram that strongly depends on strength and orientation of an external magnetic field as well as on the history of its application. We conducted combined experiments of resonant elastic x-ray scattering (REXS) and Lorentz transmission electron microscopy (LTEM) on an identical lamella of Mn1.4PtSn. Our complementary approach allows for an unambiguous correlation of the real space magnetic textures in Mn1.4PtS, i.e., helices, non-topological (NT) bubbles and aSks as determined by LTEM and transitions between them with their corresponding k space scattering patterns obtained by REXS. The octupole vector magnet of the REXS setup enabled us to gain extended information on the dependence of the phase diagram of $Mn_{1.4}PtSn$ on the direction of the external field, revealing the interplay of chiral soliton lattices, NT bubbles, the conical phase and aSks. Part of this work is gratefully supported by DFG within SPP 2137.

MA 12.6 Tue 10:45 HSZ 02

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], Volodymyr Kravchuk[2], Arnaud Magrez[1], Helmuth Berger[1], Thomas Schönenberger[1], Henrik M. Rønnow[1], and Dirk Grundler[1] — [1]École Polytechnique Fédérale de Lausanne, Switzerland — [2]Karlsruhe Institute of Technology, Germany

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 in the small wavevectors limit, $k \ll k_h$, 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 analysed 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 weights. The theoretical results are compared to a BLS experiment in the backscattering geometry that probe magnons with a wavevector $k = 48 rad/\mu m < k_h = 105 rad/\mu m$. 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 is clearly identified.

MA 12.7 Tue 11:00 HSZ 02

Modelling thermal transport in spiral magnets — •Margherita Parodi[1,2] and Sergey Artyukhin[2] — [1]University of Genova, Italy — [2]Italian Institute of Technology, Genova, Italy

Magnetic memory and logic devices, including prospective ones based on skyrmions, inevitably produce heat. Thus, controlling heat flow is essential for their performance. Here we study magnon contribution to thermal conductivity in the most basic non-collinear magnet with a spin spiral ground state. Non-collinearity leads to anharmonic terms, resulting in magnon fusion and decay processes. These processes determine the magnon lifetime which can be used to estimate thermal conductivity in single mode approximation. However, by solving the full Boltzmann equation numerically, we find much higher thermal conductivity. This signifies that heat is carried not by individual magnons but by their linear combinations, called relaxons. The thermal conductivity is found to be increasing with the diminishing twist angle, consistent with recent experiments. The results pave the path to understanding magnetic thermal transport in other non-collinear magnets.

MA 12.8 Tue 11:15 HSZ 02

Enhanced Skyrmion Diffusion by Periodic Excitation — •Raphael Gruber, Maarten Brems, Jan Rothörl, Tobias Sparmann, Fabian Kammerbauer, Iryna Kononenko, Maria-Andromachi Syskaki, Peter Virnau, and Mathias Kläui — Institut für Physik, Johannes-Gutenberg Universität Mainz, 55099 Mainz, Germany

Magnetic skyrmions are chiral, quasi-particle spin structures that are considered as promising candidates for data storage, logic and non-conventional computing devices. When thermal excitation of the spins overcomes the variations in the energy landscape of a sample, skyrmions exhibit thermal motion as recently reported [1]. For non-conventional computing, diffusion is essential and its speed is key. Although pinning slows down diffusion, a finite effect of pinning is even required in order to ensure the system's complexity and non-linearity for non-conventional computing [2]. Using magneto-optical Kerr microscopy, we demonstrate that we can drastically increase the diffusion coefficient of micrometer-sized skyrmions in magnetic thin films by excitation with oscillating magnetic fields. The faster motion is traced back to a reduction of the effective pinning since the skyrmion pinning is strongly size-dependent [3]. Our findings thus pave the way to a significant increase of both performance and reliability of skyrmion devices, especially in non-conventional computing.

[1] Zázvorka, et al. Nat. Nanotechnol. 14, 658-661 (2019) [2] Raab et al. Nat Commun 13, 6982 (2022). [3] Gruber et al. Nat Commun 13, 3144 (2022).

MA 13: Focus Session: New Perspectives for Adiabatic Demagnetization Refrigeration in the Kelvin and sub-Kelvin Range (joint session TT/MA)

Efficient cooling into the Kelvin and sub-Kelvin range is a long-standing challenge relevant to both fundamental research and future quantum technologies. The standard cooling cycle based on vapor compression exploits expensive and rare helium. Low-temperature physicists world-wide are presently looking for cheaper and accessible alternatives, not to mention the need of compact cooling technology for desktop quantum technology, or special requirements for applications such as space missions and scanning tunneling microscopes. One of the key candidates is adiabatic demagnetization refrigeration (ADR). ADR is based on magnetic solids with a huge magnetocaloric effect and requires no helium. Even if paramagnetic salts are known and used for ADR applications for almost a century, there is an ongoing quest for materials with better magnetocaloric and mechanical properties, thermal conductivity, and vacuum compatibility. In this symposium, new fundamental ideas and the recent successful design and characterization of quantum materials for improved ADR will be highlighted. These materials exploit collective phenomena in correlated electron systems, such as the concept of geometrically frustrated magnetism to push the entropy to low temperatures, as well as heavy-fermion, and quantum-critical states.

Organizers: Andreas Honecker (CY Cergy Paris Université) and Jürgen Schnack (Universität Bielefeld)

Time: Tuesday 9:30–13:15 Location: HSZ 03

Invited Talk MA 13.1 Tue 9:30 HSZ 03

Self-cooling molecular spin quantum processors — •Marco Evangelisti[1], Fernando Luis[1], Elias Palacios[1], David Aguilà[2], and Guillem Aromí[2] — [1]INMA, CSIC & Universidad de Zaragoza, Spain — [2]Dept. Química Inorgànica, Universidad de Barcelona, Spain

Cryogenic refrigeration is crucial for a wide range of emerging applications in the field of quantum technologies. Indeed, thermal energy must be minimized to avoid the excitation of vibrational motions that could disturb quantum operations. Synthetic chemistry provides a sophisticated methodology for the design and synthesis of materials displaying a wide variety of properties. Molecular materials are capable of excellent and unique characteristics that can be exploited either for caloric cooling[1] or spin-based quantum computing[2]. However, these features are not yet being implemented as such to act together within the same material, that is, at the molecular scale. Here, we show that a spin qubit (or qudit) can be brought into proximity with a spin centre that acts as a cooler. To this end, we make use of rare-earth-based asymmetric molecular dimers. A chemically engineered structural asymmetry introduces different coordination environments for each metal ion, operating similarly as for molecular quantum gates reported by some of us[3]. This strategy allows selecting individually both constituent ions, leading to e.g. the direct observation of the cooling of a single Er(III) ion qubit, or a Tm(III) electronuclear spin qudit, driven chiefly by the demagnetization of a single Gd(III) ion located within the same molecule.

[1] Dalton Trans. 39, 4672 (2010)
[2] Nat. Chem. 11, 301 (2019)
[3] Phys. Rev. Lett. 107, 117203 (2011)

Invited Talk MA 13.2 Tue 10:00 HSZ 03

Triangular rare-earth borates for milli-Kelvin adiabatic demagnetization refrigeration — •Philipp Gegenwart — Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg

Adiabatic demagnetization refrigeration (ADR) is a classical cooling technique with renewed recent attention as alternative to costly and elaborate $^3He/^4He$ dilution refrigeration. Established water containing ADR salts suffer from chemical instability which requires delicate treatment to avoid degradation and ensure good thermal contact. Water-free $KBaYb(BO_3)_2$ is an excellent alternative with high entropy density that allows ADR to below 20 mK [1]. Sintered pellets with silver powder admixture to ensure good thermal coupling are easy to manufacture, inexpensive and long-term stable even upon heating up to 700°C, enabling also ultra-high vacuum applications. $KBaYb(BO_3)_2$ belongs to a family of rare-earth-based borates with triangular arrangement of magnetic moments. We discuss the impact of geometrical frustration and structural randomness on its low-temperature properties and demonstrate the enormous tunability of cooling power and operating temperature by chemical substitution.

[1] Y. Tokiwa, S. Bachus, K. Kavita, A. Jesche, A.A. Tsirlin, and P. Gegenwart, Commun. Mater. 2 (2021) 42.

Invited Talk MA 13.3 Tue 10:30 HSZ 03

A millikelvin scanning tunnelling microscope in ultra-high vacuum with adiabatic demagnetisation refrigeration — •Ruslan Temirov — Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, Germany — University of Cologne, Institute of Physics II, Cologne, Germany

Scanning tunnelling microscopes (STMs) operating in ultra-high vacuum (UHV) and low-temperature conditions are used widely for imaging and precise manipulation of surface nanostructures. A growing interest in studies of quantum-coherent phenomena in such nanostructures stimulates the development of STMs that operate at very low millikelvin temperatures. This contribution presents the design of a first-ever UHV STM cooled by adiabatic demagnetisation refrigeration (ADR) to below 30 mK. The use of ADR makes the STM design modular and helps it to reach a remarkable degree of mechanical stability. Tunnelling spectra collected on an atomically clean superconducting Al(100) surface reveal that the electronic temperature of the tunnelling junction is less than 80 mK. The inelastic electron tunnelling spectroscopy of an individual electron spin performed in magnetic fields of up to 8 Tesla validates the STM capabilities for quantum nanoscience research.

15 min. break

Invited Talk MA 13.4 Tue 11:15 HSZ 03

ADR cryostats in low temperature physics and their applications — •Doreen Wernicke — Entropy GmbH, Gmunder Str. 37a, 81379 München

Entropy GmbH is a company founded in 2010 in Munich, Germany, specializing in the development and manufacture of low temperature cryostats. All Entropy cryostats are based on closed-cycle pre-cooling to temperatures below 3K. Further cooling stages such as ADR units, Joule-Thomson stages, and dilution refrigerators including electronics and software are proprietary developments. The modular design of all cryostats offers the possibility of adaptation to many different experiments and applications. One of Entropy's most common products are the ADR cryostats. The presentation will explain the principle of ADR cooling and features such as base temperature and holding time at operating temperature. Applications for low temperature device operation such as various types of superconducting detectors (TES, MKIDs, SQUIDs, SNSPDs) and Qubit characterization will be presented to demonstrate the performance and limitations of adiabatic demagnetization refrigeration.

Invited Talk MA 13.5 Tue 11:45 HSZ 03

Frustrated dipolar materials for low-temperature magnetic refrigeration — •Mike Zhitomirsky — Institute of Interdisciplinary Research, CEA-Grenoble, France

Low-temperature refrigeration is crucial for emergent quantum-information technologies and other scientific applications that outstretch from space telescopes to medicine. This growing demand fuels an interest in alternative low-temperature techniques including the adiabatic demagnetization refrigeration. The existing ADR technologies for the sub-Kelvin range utilize dilute paramagnetic salts of Cr and Fe magnetic ions, which have limited efficiency at higher temperatures. I shall discuss general directions of the ongoing search of prospective refrigerant materials by exploring collective effects in systems of interacting magnetic moments as opposed to noninteracting moments in paramagnetic salts. Specifically, I focus on geometrically frustrated magnets with a residual ground-state degeneracy as well as on dipolar magnets. I present new experimental and theoretical results obtained recently in Grenoble for two dipolar materials: $Yb_3Ga_5O_{12}$, which is a spin-1/2 dipolar ferromagnet on a hyper-Kagome lattice, and $GdLiF_4$, which exhibits a hidden magnetic frustration. The striking properties of the latter material including a fractional magnetization plateau demonstrate importance of new magnetocaloric materials not only for applied but also for basic research in magnetism.

MA 13.6 Tue 12:15 HSZ 03

ADR based sub-Kelvin cryostats for applied quantum technologies — •Pau Jorba[1], Felix Rucker[1], Steffen Säubert[1], Alexander Regnat[1], Jan Spallek[1], and Christian Pfleiderer[2] — [1]kiutra GmbH, Flößergasse 2, D-81369 München, Germany — [2]Physik-Department, Technische Universität München, D-85748 Garching, Germany

In view of the increasing demand for the cooling of quantum electronic devices, the development of scalable cooling solutions that provide low temperatures independent of rare helium-3 will be mandatory for the adoption and commercial use of next-generation quantum technologies. We present novel ADR based sub-Kelvin cryostats[1] specifically developed for the characterization and operation of quantum devices. We address how known challenges of ADR systems such as limited hold time and magnetic stray fields can be overcome. Specifically, we describe how continuous sub-Kelvin cooling and wide-range temperature control can be achieved by combining multiple ADR units and mechanical thermal switches. We also present a novel sample loader mechanism[2] that allows taking advantage of the solid-state nature of ADR and to cool samples from room temperature to 100 mK in less than 3 hours.

[1] Regnat et al. (2018) Cryogen-free cooling apparatus (EP 3163222). European Patent Office.
[2] Spallek et al. (2022) System and method for inserting a sample into a chamber (EP 3632560). European Patent Office.

MA 13.7 Tue 12:30 HSZ 03

ADR below the ordering temperature in triangular $KBaGd(BO_3)_2$ — •Noah Winterhalter-Stocker[1], Alexander Bellon[1], Fabian Hirschberger[1], Sebastian Bachus[1], Sebastian Erdmann[1], Alexander Tsirlin[1,2], Yoshifumi Tokiwa[1,3], Anton Jesche[1], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86159 Augsburg, Germany — [2]Felix Bloch Institute for Solid-State Physics, Leipzig University, D-04103 Leipzig, Germany — [3]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

Compared to the triangular ADR magnet $KBaYb(BO_3)_2$ [1] the isotructural sister compound $KBaGd(BO_3)_2$ with spin 7/2 moments has a three times enhanced magnetic entropy density of 192 $mJK^{-1}cm^{-3}$. We report a low-temperature magnetic and thermodynamic investigation of polycrystalline $KBaGd(BO_3)_2$ down to 50 mK. Specific heat indicates an antiferromagnetic phase transition at 263 mK, strongly broadened due to randomness and frustration, that becomes suppressed beyond 0.5 T. Further increase of magnetic field shifts the available entropy of R log 8 towards high temperatures. Interestingly, ADR of a pellet utilizing the same setup as used in [1] reveals a minimal temperature if $T_{\min}$=122 mK that is more than twice below T_N along with a hold time of more than 8 hours. The combination of minimal temperature and entropy density in $KBaGd(BO_3)_2$ is outstanding among known ADR materials.

[1] Y. Tokiwa *et al.*, Communications Materials **2.1**, 1-6 (2021)

MA 13.8 Tue 12:45 HSZ 03

Magnetocaloric properties of $(RE)_3Ga_5O_{12}$ (RE=Tb, Gd, Nd, Dy) — Markus Kleinhans[1], Klaus Eibensteiner[1,2], Jon Leiner[1], •Christoph Resch[1], Lukas Worch[1], Marc Wilde[1], Jan Spallek[1,2], Alexander Regnat[1,2], and Christian Pfleiderer[1] — [1]Physik Department, Technical University Munich, D-85748 Garching, Germany — [2]kiutra GmbH, Rupert-Mayer-Str. 44, D-81379 Munich, Germany

We report the characteristic magnetic properties of several members of the rare earth garnet family, $Gd_3Ga_5O_{12}$ (GGG), $Dy_3Ga_5O_{12}$ (DGG), $Tb_3Ga_5O_{12}$ (TGG), and Nd_3Ga5O_{12} (NGG), and compare their relative potential utility for magnetocaloric cooling, including their minimal adiabatic demagnetization refrigeration (ADR) temperatures and relative cooling parameters. A main objective of this work was to find potential improvements over the magnetocaloric properties of GGG for use in low temperature ADR cryostats. Using Tb^{+3} and Dy^{+3} in the RE-site oers, in principle, a higher saturation magnetization and Nd^{+3} gives a lower de Gennes factor and therefore potentially low transition temperature. Our results show that $Dy_3Ga_5O_{12}$ yields an optimal relative cooling parameter (RCP) at low applied fields and a low transition temperature, which would allow for the design of more efficient ADR cryostats.

[1] M. Kleinhans et al., arXiv/2204.01752; Phys. Rev. Appl. in press (2022).

MA 13.9 Tue 13:00 HSZ 03

Study of the large rotational magnetocaloric effect in $Ni(en)(H_2O)_4SO_4{\cdot}2H_2O$ — •Róbert Tarasenko, Petro Danylchenko, Erik Čižmár, Vladimír Tkáč, Alexander Feher, Alžbeta Orendáčová, and Martin Orendáč — Institute of Physics, Faculty of Science, Pavol Jozef Šafárik University, Park Angelinum 9, 041 54 Košice, Slovakia

The title compound $Ni(en)(H_2O)_4SO_4{\cdot}2H_2O$ (en = ethylenediamine) has been identified as a spin-1 paramagnet with the nonmagnetic ground state introduced by the easy-plane anisotropy $D/k_B = 11.6$ K with $E/D = 0.1$ and negligible exchange interactions $J \approx 0$. We present an experimental study of the rotational magnetocaloric effect (MCE) in single crystals at temperatures above 2 K, associated with adiabatic crystal rotation between the easy plane and hard axis in magnetic fields up to 7 T. The experimental observations are completed with *ab* initio calculations of the anisotropy parameters. Theoretical simulations of the rotational MCE in the $S = 1$ paramagnet were performed and the simulations were compared with experimental data. A large rotational magnetic entropy change ≈16.9 $Jkg^{-1}K^{-1}$ has been achieved in 7 T. The adiabatic rotation of the crystal in 7 T starting at the initial temperature of 4.2 K leads to the cooling of the sample down to 0.34 K, which suggests the application of this material in low-temperatures cooling. Our simulations show that $S = 1$ Ni(II)-based systems with easy-plane anisotropy can have better rotational magnetocaloric properties than costly materials containing rare-earth elements.

Supported by project No. APVV-18-0197.

MA 14: Surface Magnetism

Time: Tuesday 9:30–11:45 Location: HSZ 04

Invited Talk MA 14.1 Tue 9:30 HSZ 04

Antiferromagnetism-driven two-dimensional topological nodal-point superconductivity — •Roberto Lo Conte[1], Maciej Bazarnik[1,2], Eric Mascot[1], Krisztián Palotás[3], Levente Rózsa[4], László Szunyogh[3], André Kubetzka[1], Dirk K. Morr[5], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, Germany — [2]Institute of Physics, Poznan University of Technology, Poland — [3]Department of Theoretical Physics, Budapest University of Technology and Economics, Hungary — [4]Department of Physics, University of Konstanz, Germany — [5]Department of Physics, University of Illinois at Chicago, USA

In the recent years, pioneering studies have been carried out on magnet/superconductor hybrid systems[1-4], motivated by their potential to host emergent quantum phases such as topological superconductivity. Here, we present the discovery of a topological nodal-point superconducting phase in antiferromagnetic manganese (Mn) monolayer islands on superconducting niobium (Nb) via low temperature spin-polarized STM[5]. Low-energy edge modes are found to separate the topological phase from the trivial one. The relative spectral weight of the edge modes depends on the edge's atomic configuration, which is a fingerprint of the discovered topological state. [1]S. Nadj Perge et al., Science 346, 602(2014). [2]A. Palacio-Morales et al., Sci. Adv. 5, eaav6600(2019). [3]L. Schneider et al., Nat. Phys. 17, 943(2021). [4]S. Kezilebieke et al., Nature 588, 424(2020). [5]R. Lo Conte et al., PRB 105, L100406(2022). M. Bazarnik et al., arXiv:2208.12018(2022).

MA 14.2 Tue 10:00 HSZ 04

Structure–Property Relationship of Reversible Magnetic Chirality Tuning — •Jing Qi[1], Paula M. Weber[1], Tilman Kisslinger[2], Lutz Hammer[2], M. Alexander Schneider[2], and Matthias Bode[1] — [1]Julius-Maximilians-Universitaet Wuerzburg, Germany — [2]Universitaet Erlangen-Nuernberg, Germany

The Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction mediates collinear magnetic interactions via the conduction electrons of a non-magnetic spacer, resulting in a ferro- or antiferromagnetic magnetization in magnetic multilayers [1]. Recently it has been discovered that heavy non-magnetic spacers are able to mediate an indirect magnetic coupling that is non-collinear and chiral. This Dzyaloshinskii-Moriya-enhanced RKKY (DME-RKKY) interaction causes the emergence of a variety of interesting magnetic structures, such as skyrmions and spin spirals [2]. Here, we show by spin-polarized STM that the interchain coupling between manganese oxide chains on Ir(001) can reproducibly be switched from chiral to collinear antiferromagnetic by increasing the oxidation state of MnO_2 while the reverse process can be induced by thermal reduction. The underlying structure–property relationship is revealed by low-energy electron diffraction intensity (LEED-IV) analysis. Density functional theory calculations suggest that the magnetic transition may be caused by a significant increase of the Heisenberg exchange which overrides the DMI interaction upon oxidation.

[1] P. Bruno et al., Phys. Rev. Lett. **67**, 1602-1605 (1991).
[2] M. Schmitt et al., Nat. Commun. **10**, 2610 (2019).

MA 14.3 Tue 10:15 HSZ 04

Lifting the frustration of higher-order exchange interactions in ultrathin films — •Felix Nickel[1], Soumyajyoti Haldar[1], Roland Wiesendanger[2], Stefan Heinze[1], and Kirsten von Bergmann[2] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]Department of Physics, University of Hamburg

The 3Q state – a three-dimensional spin structure on a two-dimensional lattice predicted about 20 years ago [1] – has been observed in a Mn monolayer on Re(0001) using spin-polarized scanning tunneling microscopy (SP-STM) [2]. The 3Q state is a superposition of three symmetry equivalent spin spirals with the same period and can be stabilized by higher-order exchange interactions (HOI) such as the biquadratic or four-spin interactions [1,2]. Recently, it has been suggested based on density functional theory (DFT) calculations that the 3Q state in Mn/Re(0001) is significantly distorted due to topological chiral magnetic interactions [3]. Here, we show using DFT that the competition of biquadratic, four-spin, and topological chiral interactions can be tuned in Mn/Re(0001) by single atomic adlayers of Pd or Rh. Thereby, the frustration of HOI present in Mn/Re(0001) is lifted which results in the occurrence of the ideal 3Q state. SP-STM experiments confirm the predicted 3Q ground state of Pd/Mn/Re(0001) and Rh/Mn/Re(0001) and reveal differences to Mn/Re(0001).

[1] Ph. Kurz *et al.*, Phys. Rev. Lett. **86**, 1106 (2001)
[2] J. Spethmann *et al.*, Phys. Rev. Lett. **124**, 227203 (2020)
[3] S. Haldar *et al.*, Phys. Rev. B **104**, L180404 (2021)

15 min. break

MA 14.4 Tue 10:45 HSZ 04

Conical spin-spirals at a ferromagnet's surface: experimetal observations — •Patrick Haertl[1], Gustav Bihlmayer[2], Markus Leisegang[1], Stefan Bluegel[2], and Matthias Bode[1] — [1]Universität Würzburg, Germany — [2]Forschungszentrum Jülich and JARA, Germany

The spin-orbit–driven Dzyaloshinskii-Moriya interaction (DMI) can lead to chiral spin structures in magnetic systems with broken inversion symmetry [1]. The purely interfacial origin of DMI generally results in a reciprocal scaling with the magnetic layer thickness [2]. Here we report on the observation of a conical spin-spiral state at the surface of epitaxial Gd(0001) films grown on W(110). In a recently performed spin-polarized scanning tunneling microscopy (SP-STM) investigation of the thickness-dependent domain structures of Gd/W(110) we confirmed the existence of a spin reorientation transition (SRT) [3] from in-plane to out-of-plane magnetized films at a critical thickness $\Theta_{\mathrm{crit}} \approx (100 \pm 20)$ AL [4]. In the vicinity of this SRT, we identify striped regions with a periodicity of about 2 nm. The application of an external magnetic field induces a rearrangement of the stripes, thereby unambiguously confirming its magnetic origin. The experimental observations are discussed on the basis of density functional theory (DFT).

[1] T. Moriya, Phys. Rev. **120**, 91-98 (1960).
[2] J. Cho et al., Nature Comm. **6**, 7635 (2015).
[3] A. Berger et al., Phys. Rev. B **52**, 1078 (1995).
[4] P. Härtl et al., Phys. Rev. B **105**, 174431 (2022).

MA 14.5 Tue 11:00 HSZ 04

Conical spin-spirals at a ferromagnet's surface: a theoretical analysis — •Gustav Bihlmayer[1], Patrick Härtl[2], Markus Leisegang[2], Matthias Bode[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Universität Würzburg, Germany

The properties of surface layers of a magnetic material can differ substantially from those of the bulk material. A prominent example is the Dzyaloshinskii-Moriya interaction (DMI), resulting from inversion-symmetry breaking at the surface, but also the magnetic anisotropy and the exchange interactions are locally modified. Gd(0001) is here a well-investigated model surface but despite its sensitivity of exchange interactions to the local environment, experimental data indicated that it behaves as homogeneous Heisenberg system [1]. Recent observations of spin-spirals at the surface of epitaxial Gd(0001) with spin-polarized scanning tunneling microscopy let us re-investigate this system. Density functional theory (DFT) calculations show that not only a sizable DMI can be found at the Gd(0001) surface but also the exchange interactions are modified to drive the system locally towards a conical spin-spiral state. Since the magnetic anisotropy and the exchange interactions with the ferromagnetic bulk material disfavor non-collinear magnetic states, only slight modifications of the exchange interactions make these spirals visible. We explore the phase diagram numerically and with the help of atomistic spin-dynamics simulations.

[1] C. S. Arnold and D. P. Pappas, Phys. Rev. Lett. **85**, 5202 (2000)

MA 14.6 Tue 11:15 HSZ 04

Non-collinear spin structure of trilayer Mn films on W(001) — •Tim Drevelow[1], Paula M. Weber[2], Jing Qi[2], Matthias Bode[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany — [2]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Wilhelm Conrad Röntgen-Center for Complex Material Systems (RCCM), Universität Würzburg, Am Hubland, 97074 Würzburg, Ger-

many

The spin structure of Mn films on the W(001) surface depends sensitively on the number of atomic layers. It has been shown that a Mn monolayer exhibits a spin spiral driven by the Dzyaloshinskii-Moriya interaction (DMI) [1] while the Mn double layer possesses an antiferromagnetic checkerboard state and vanishing Mn moments at the interface [2]. Here, we study the Mn trilayer on W(001) with a combination of spin-polarized scanning tunneling microscopy (SP-STM) and density functional theory (DFT) calculations. Experimentally, it is shown that the Mn films grow pseudomorphically and exhibit a c(4×2) magnetic superstructure consistent with a conical spin spiral ground state. Based on our DFT calculations we compare the total energies of different collinear and non-collinear spin structures including the effect of spin-orbit coupling. We find a complex interplay of magnetic interactions and structural relaxations of the Mn trilayer.

[1] Ferriani *et al.* Phys. Rev. Lett. **101**, 027201 (2008).
[2] Meyer *et al.* Phys. Rev. Research **2**, 012075(R) (2020)

MA 14.7 Tue 11:30 HSZ 04

Structural transitions of magnetic thin films induced by two-dimension materials — •Hangyu Zhou[1,2], Manuel dos Santos Dias[1,3,4], Weisheng Zhao[2], and Samir Lounis[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulations, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]School of Integrated Circuit Science and Engineering, MIIT Key Laboratory of Spintronics, Beihang University, Beijing 100191, China — [3]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [4]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

Interfaces of magnetic thin films play a key role in determining magnetic behaviors and implementations of spintronic devices. In the last decade, the increased availability of high-quality two-dimensional (2D) materials has helped to broaden the scope of interfaces, leading to the discovery of novel electronic and magnetic properties. Here, we explore with density functional theory calculations the impact of hexagonal boron nitride (h-BN) on the magnetism and structural properties of magnetic monolayers placed on heavy metal surfaces. We found that h-BN induces various structural transitions, and we investigate how magnetic interactions, such as the Heisenberg exchange interaction and the Dzyaloshinskii-Moriya interaction (DMI), are influenced by these reconstructions. These results contribute to new avenues for stabilizing complex spin-textures.

Work funded by DFG (SPP 2244; LO 1659/7-1) and China Scholarship Council program.

MA 15: INNOMAG e.V. Prizes 2023 (Diplom-/Master and Ph.D. Thesis)

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Dissertationspreis und einen Diplom-/Masterpreis ausgeschrieben, welche auf der Tagung der DPG 2023 in Dresden 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 2023. Talks will be given in English!

Time: Tuesday 9:30–11:50 Location: HSZ 401

MA 15.1 Tue 9:30 HSZ 401

Cubic magneto-optic Kerr effect in Ni(111) thin films — •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 — [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, to detect spin-orbit torque or to image antiferromagnetic domains.

In our study, we observe a strong anisotropic MOKE contribution of third order in $\boldsymbol{M}$ in Ni(111) thin films, attributed to a cubic magneto-optic tensor $\propto \boldsymbol{M}^3$ [1]. This cubic MOKE (CMOKE) is responsible for a threefold in-plane angular dependence of the magnetically saturated longitudinal MOKE response. We further show that this angular dependence is affected by the amount of structural domain twinning in the sample. The degree of twinning is determined by off-specular X-ray diffraction. Finally, the dependence of the anisotropic CMOKE on the external magnetic field strength is investigated up to nearly 2 T. 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] M. Gaerner et al., arXiv: 2205.08298

MA 15.2 Tue 9:50 HSZ 401

Switching of Sublattice Magnetization in Quantum Antiferromagnets Described by Schwinger Bosons — •Katrin Bolsmann — Technische Universität Dortmund

Harvesting magnetic excitations in antiferromagnets for information processing is a promising and fast-growing field in the research of magnetism. One of the main foci is the readout and manipulation of the Néel vector of antiferromagnetic (AFM) materials. We study a theoretical approach to describe the non-equilibrium switching of a two-dimensional AFM magnetization on a square lattice. We recall the use of Schwinger bosons in equilibrium to describe the elementary excitations, of the isotropic and anisotropic AFM square lattice, in mean-field approximation. The Bose-Einstein condensation of Schwinger bosons describes the long-range magnetic order. Then, the Schwinger boson mean-field theory is applied to investigate the switching of the sublattice magnetization on the AFM square lattice via an external magnetic field. In the anisotropic system, there is an increase in energy after switching, which depends on the degree of anisotropy. Furthermore, we find a threshold field, below which switching is no longer possible, and investigate its dependence on the anisotropy. Even for low anisotropy, the threshold for the magnetic field turns out to be too large for standard technical applications. Finally, we discuss possible modifications of the protocol to enable switching of the sublattice magnetization with smaller fields.

MA 15.3 Tue 10:10 HSZ 401

Magnetooptical Investigation of nonreciprocal Phonon-Magnon Interaction — •Yannik Kunz[1], Michael Schneider[1], Moritz Geilen[1], Matthias Küss[2], Manfred Albrecht[2], Philipp Pirro[1], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Universität Augsburg

The coupling of surface acoustic waves (SAWs) with spin waves (SWs) intrinsically breaks the time-inversion symmetry. The resulting nonreciprocity can be exploited for applications such as miniaturized microwave isolators. SAWs can be efficiently excited and detected by interdigital transducers. Therefore, in experiments the magnetic field dependent transmission induced by the coupling with SWs is commonly detected via electrical methods [1]. However, for the investigation of magnetoelastic interactions with spatial resolution, magnetooptical measurement methods are needed. We employed microfocused Brillouin light scattering spectroscopy and frequency-resolved magneto-optical Kerr effect spectroscopy [2] to map the spatial dependence of the phonon-magnon-coupling on a $LiNbO_3/Co_{40}Fe_{40}B_{20}$(10 nm)/SiN(5 nm)-structure. Our experiments provide direct evidence for coherent and nonreciprocal conversion of phonons to magnons along the SAW propagation path.

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 Magnetics Letters 10, 5503905 (2019).

MA 15.4 Tue 10:30 HSZ 401

The Turn of the Screw and the Slide of the Skyrmion — •Nina del Ser — Institute for Theoretical Physics, University of Cologne

We explore the non-equilibirum dynamics of chiral magnets driven by oscillating magnetic fields in the GHz regime. Universal activation of the magnets' translational and rotational Goldstone modes invites many exciting applications. Magnetic screws will turn, skyrmions will swim and skyrmion lattices will rotate. The magnetic Archimedean screw opens the door to new transport applications on the nano-scale, and is shown to be a very efficient electron pump even in the presence of disorder. At stronger driving, Floquet spin wave instabilities provoke the formation of a time quasicrystal, where the magnetisation oscillates at new incommensurate spatial and temporal frequencies. We also investigate the role of fractional charge topological charge in magnets. We show that such charges turn up for example in cubic magnets and in the fragments of exploding skyrmions or trapped between symmetry-broken domain walls. We show how their remarkable scattering properties can be used to build a magnon-powered fractional defect engine.

MA 15.5 Tue 10:55 HSZ 401

Imaging vortex pinning and gyration by time-resolved and in-situ Lorentz microscopy — •Marcel Möller — Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — 4th Physical Institute - University of Göttingen, Göttingen, Germany

Nanoscopic magnetic textures, including vortices, merons and skyrmions promise future applications three-dimensional memory, logic gates or neuromorphic computing. Studying the control of such textures employing electric, magnetic or optical fields, demands instruments with sufficient spatial and temporal resolution. Ultrafast transmission electron microscopy allows for the study of optically-driven dynamics in materials. Yet, its potential to probe current- or field-driven dynamics of magnetic textures has remained unexplored.

In this work, ultrafast Lorentz imaging is developed to map the time-resolved gyration of vortices in a magnetic nanostructure driven by radio-frequency currents. The tracking of the vortex core with a localization precision of ± 2 nm and a temporal resolution below 3 ps is demonstrated [1]. Moreover, we find a transient change in the frequency and damping of the core orbit, attributed to structural disorder in the sample. Combining time-resolved Lorentz microscopy with bright-field imaging is used to identify the origin of this disorder, indicating grain boundaries in the polycrystalline film to be a major source of pinning [2].

[1] M. Möller *et al.*, Commun Phys 3, 36 (2020).
[2] M. Möller *et al.*, Phys. Rev. Research 4, 013027 (2022).

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

MA 16: Magnonics

Time: Tuesday 9:30–12:00 Location: HSZ 403

MA 16.1 Tue 9:30 HSZ 403

Resonances in periodically driven magnon systems — •Jan Mathis Giesen, Christoph Dauer, Imke Schneider, Sebastian Eggert, Alexandre Abbass Hamadeh, and Philipp Pirro — Department of Physics and Research Center Optimas, Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany

Parametric resonances in ferro- and ferri-magnetic systems under a periodic drive are known for quite some while. So called parallel pumping, which is for example used to realize Magnon BECs in materials like YIG, is normally achieved by driving the system with twice the frequency of a certain magnon mode. Much less research has been dedicated to lower lying resonances, which in theory should also be possible and give rise to some interesting behaviours.

We establish a method based on Floquet theory to efficiently determine and examine instabilities of the microscopic magnon system. As a central consequence parametric resonances occur if the driving frequency is an integer multiple of two times the energy of the elementary excitation. In particular we examine regions of resonances for frequencies below the energy spectrum and predict different effects depending on the driving amplitude and frequency, like the vanishing of instabilities at high driving fields. We compare our results with phenomenological approaches to investigate the role damping plays in such systems and perform micromagnetic simulations in order to confirm our results.

MA 16.2 Tue 9:45 HSZ 403

Topological Hybrids of Magnons and Magnon Bound Pairs — Alexander Mook[1], •Rhea Hoyer[1], Jelena Klinovaja[2], and Daniel Loss[2] — [1]Johannes Gutenberg-University, Mainz, Germany — [2]University of Basel, Basel, Switzerland

We employ anisotropic and spin-nonconserving Heisenberg models on Bravais lattices to predict the existence of topological quantum spin excitations in ferromagnets. We show that a hybridization of a single magnon and a two-magnon bound state can lead to topological spectral gaps that support quantum-Hall-like edge excitations. Such topological chiral hybrids of magnons and magnon pairs are a quantum phenomenon that vanishes in the classical limit and goes beyond the established theory of magnon topology.

Reference: Mook, Hoyer, Klinovaja, Loss, arXiv:2203.12374.

MA 16.3 Tue 10:00 HSZ 403

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, Bautzner Landstraße 400, 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 a linearized version of the equation of motion of the magnetization numerically 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 the magnonics community but FEM simulations in general), covering several classes of sample geometries and, soon, 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 16.4 Tue 10:15 HSZ 403

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, RPTU Kaiserslautern-Landau, 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 arises, 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 itself in the confinement of the magnon BEC, which exhibits an enhanced lifetime due to the continuous influx of magnons.

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – TRR 173 – 268565370 (project B04).

15 min. break

MA 16.5 Tue 10:45 HSZ 403

Time-correlated nonlinear spiking spin waves in Ga:YIG — •David Breitbach[1], Moritz Bechberger[1], Björn Heinz[1], Jan Maskill[1], Bert Lägel[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Nonlinear spin-wave phenomena are key for magnon-based information processing and have led to the realization of numerous building blocks for spin-wave based computing. For coherent spin waves, the nonlinear frequency shift is one of the most robust nonlinear effects. In this study, we utilize this effect to build a spin-wave reservoir with temporal signal correlation. We apply time-resolved BLS microscopy to investigate the coherent excitation of spin waves by a microantenna in an in-plane magnetized, gallium-substituted yttrium iron garnet film. This system exhibits an exchange-dominated dispersion relation and PMA, resulting in a positive nonlinear frequency shift. We observe a strongly power-dependent nonlinear excitation and show that the nonlinear frequency shift creates an effective interaction between successive spin-wave excitations. This effectively serves as a fading memory in the system which can be used to temporally correlate input signals. Our work provides a foundation for future implementations of reservoir and neuromorphic computing in magnonic systems. This research is funded by the DFG - Project No. 271741898 and TRR 173-268565370 (B01) and by the ERC Grant No. 101042439 'CoSpiN'.

MA 16.6 Tue 11:00 HSZ 403

Simultaneous multitone microwave emission by DC-driven spintronic nano-element — •A. Hamadeh[1], D. Slobodianiuk[2,3], R. Moukhader[4], G. Melkov[2], V. Borynskyi[3], M. Mohseni[1], G. Finocchio[4], V. Lomakin[5], R. Verba[3], G. de Loubens[6], P. Pirro[1], and O. Klein[7] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Taras Shevchenko National University of Kyiv, Kyiv 01601, Ukraine — [3]Institute of Magnetism, Kyiv 03142, Ukraine — [4]Dept. Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, 98166 Messina, Italy — [5]Center for Magnetic Recording Research, University of California San Diego, La Jolla, California 92093-0401, USA — [6]SPEC, CEA, CNRS, Université Paris-Saclay, 91191 Gif-sur-Yvette, France — [7]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, INAC-Spintec, 38054 Grenoble, France

The generation of microwave radiation by DC-driven spintronic elements is generally considered a process that generates only one frequency at a time. In our study however, we can show by means of experimental data, micromagnetic simulations, and an analytical model that several frequencies can be generated simultaneously due to nonlinear magnon coupling. This discovery opens the way for entirely new multiplexing techniques and synchronization mechanisms that can be used for communication and neuromorphic computing.

MA 16.7 Tue 11:15 HSZ 403

Sensing magnetic excitations in two-dimensional materials with single NV-centers — •Hossein Mohammadzadeh, Dominik Maile, and Joachim Ankerhold — Institute for Complex Quantum Systems Albert-Einstein-Allee 11 D-89069 Ulm

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 a significant potential for applications ranging from topological magnonics to low-power spintronics, quantum computing, and optical communications [1]. In this talk, we theoretically investigate the possibility of sensing magnetic excitations in such materials with nitrogen-vacancy (NV) center in diamond. The NV center in diamond is an excellent platform for noninvasively detecting nanoscale signatures and magnetic domain walls [2]. We present a description of the low-energy magnetic excitations within a Kitaev-Heisenberg model for a honeycomb lattice. Coupling these excitations to the single NV-electronic spin paves the way to use magnetic noise spectroscopy to probe magnons in such a system. Utilizing Fermi*s golden rule and quantum linear response theory, we show how the spin relaxation time of the NV alters in the magnetic field induced by magnons in both bulk and topologically protected edge states. The relaxation time of the NV changes by different NV-sample distances and in various strengths of spin-spin interactions inside the material.

[1] Qing Hua Wang et al., ACS Nano, 16, 5, 6960-7079 (2022)
[2] Jörg Wrachtrup et al. Nat Commun 12, 1989 (2021)

MA 16.8 Tue 11:30 HSZ 403

Magnetic excitations in the conductive altermagnet RuO2: ab initio calculations — •Alberto Marmodoro[1], Sergiy Mankovsky[2], Hubert Ebert[2], Ilja Turek[3], Tomas Jungwirth[1], and Ondřej Šipr[1,4] — [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]Institute of Physics of Materials (IPM) of the Czech Academy of Sciences, Brno, Czech Republic — [4]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

Altermagnets 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 [1]. We report about the ab initio study of magnetic excitations in the case of the conducting, colinear antiferromagnetic altermagnet material RuO2 [2].

[1] http://doi.org/10.1103/PhysRevX.12.031042
[2] http://doi.org/10.48550/arXiv.2211.13806

MA 16.9 Tue 11:45 HSZ 403

Investigation of magnon-phonon coupling in two dimensional ferromagnetic Fe_3GeTe_2 — •Namrata Bansal[1], Qili Li[1], Paul Nufer[1], Hung-Hsiang Yang[1], Lichaun Zhang[2], Dongwook Go[2], Amir-Abbas Haghighirad[3], Yuriy Mokrousov[2,4], and Wulf Wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Peter Gruenberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1) Forschungszentrum Juelich GmbH, D-52425 Juelich — [3]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [4]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

We use inelastic tunneling spectroscopy (ITS) at 35 mK to investigate phonon-magnon coupling in the ferromagnetic van der Waals crystals Fe3GeTe2 (FGT). ITS is a powerful tool for determining the inelastic scattering of hot carriers with magnons or phonons with the second derivative of the tunneling current with respect to the bias voltage being proportional to the density of states of phonons and/or magnons. We observe excitation peaks at low energy which do not correspond to van Hove singularities of the phonon or magnon density of states but to points in their dispersion, where magnon and phonon bands cross, indicative for phonon-magnon coupling.

MA 17: Thin Films: Magnetic Anisotropy

Time: Tuesday 9:30–11:00 Location: POT 6

MA 17.1 Tue 9:30 POT 6

Micromagnetic parameters and longitudinal relaxation in ultrathin asymmetrically sandwiched magnetic films — •Oleksii M. Volkov[1], Ivan A. Yastremsky[2], Oleksandr V. Pylypovskyi[1,3], Florian Kronast[4], Claas Abert[5], Eduardo Sergio Oliveros Mata[1], Pavlo Makushko[1], Mohamad-Assaad Mawass[4], Volodymyr P. Kravchuk[6], Denis D. Sheka[2], Boris A. Ivanov[7], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [3]Kyiv Academic University, Kyiv, Ukraine — [4]Helmholtz-Zentrum Berlin für Materialen und Energie, Berlin, Germany — [5]University of Vienna, Wien, Austria — [6]Karlsruher Institut für Tech, Karlsruhe, Germany — [7]Institute of Magnetism, Nation, Kyiv, Ukraine

Ultrathin asymmetric magnetic films are a prominent material science platform, which combines unique magnetic and electronic properties enabling prospective memory and logic spin-orbitronic devices. Here, we present the quantification mechanism to distinguish all static and dynamic micromagnetic parameters of the layer stack based on magnetometry [1] and quasi-static morphology experiments on domain wall equilibrium tilts [2]. The DW damping is found to be about 0.1 [2] and it is demonstrated to arise from a longitudinal relaxation being dominant among transversal mechanisms for ultrathin films [3].

[1] I. A. Yastremsky et al., Phys. Rev. Appl. **12**, 064038 (2019).
[2] O. M. Volkov et al., Phys. Rev. Appl. **15**, 034038 (2021).
[3] I. A. Yastremsky et al., Phys. Rev. Appl. **17**, L061002 (2022).

MA 17.2 Tue 9:45 POT 6

Control of magnetoelastic coupling in Ni/Fe multilayers using He+ ion irradiation — •Giovanni Masciocchi[1,2], Gyan van der Jagt[3,4], Maria-Andromachi Syskaki[2,5], Alessio Lamperti[6], Niklas Wolff[7], Andriy Lotnyk[8], Jurgen Langer[5], Lorenz Kienle[7], Gerhard Jakob[2], Benjamin Borie[3], Andreas Kehlberger[1], Dafine Ravelosona[3], and Mathias Kläui[2] — [1]Sensitec GmbH, Mainz, Germany — [2]Johannes Gutenberg University Mainz, Mainz, Germany — [3]Spin-Ion Technologies, Palaiseau, France — [4]Universite Paris-Saclay, Gif-sur-Yvette, France — [5]Singulus Technologies AG, Kahl am Main, Germany — [6]CNR-IMM, Agrate Brianza, Italy — [7]Kiel University, Kiel, Germany — [8]Institute of Surface Engineering , Leipzig , Germany

The requirements for the magnetoelastic coefficient in thin films are often demanding. For example, magnetic sensors mostly require strain immunity, while actuators require giant strain effects. One way to obtain the desired value of the saturation magnetostriction, is to use the combination of two or more materials with different magnetic and magnetoelastic properties in a multilayer fashion. However, the material choice alone, does not allow for a local control of the magnetostriction. In this study [1], we investigate the effects of He+ irradiation on the magneto-elastic properties of a Ni/Fe multi-layered stack. The progressive intermixing caused by He+ irradiation at the interfaces of the multilayer, allows us to locally change the magnetoelastic coupling sign with increasing He+ fluences.

[1] Masciocchi, et al. Appl. Phys. Lett. 121.18 182401, 2022

MA 17.3 Tue 10:00 POT 6

Simulating the magnetic structures in twisted double bilayer CrI_3 — •Junichi Okamoto[1], Bowen Yang[2], Tarun Patel[2], and Adam Tsen[2] — [1]University of Freiburg, Freiburg, Germany — [2]University of Waterloo, Waterloo, Canada

After the discovery of superconductivity in twisted bilayer graphene at magic angles, control of material properties by twisting two-dimensional materials has emerged as "twistronics". In this talk, we will discuss the magnetic structures appearing in the Moiré superlattices of twisted double bilayer CrI_3. By using classical spin simulations, we will demonstrate that the subtle competition between the exchange anisotropy and the spatially modulated interlayer coupling is the key to understanding the experimentally observed magnetic transitions. We will further explain how the interlayer charge transport depends on the magnetic structures. The effect of various domain walls and skyrmions will also be scrutinized.

MA 17.4 Tue 10:15 POT 6

Characteristics and origin of a $SrRuO_3$ exchange spring — •Martin M. Koch, Antonia Rieche, Diana A. Rata, and Kathrin Dörr — Martin-Luther-Universität Halle-Wittenberg

A particular type of strong interface coupling between magnets is the exchange spring which resembles an interface-parallel domain wall formed in one (or both) magnets. Advances in thin film growth and resulting interface quality of magnetic oxides improve chances to observe such strong exchange coupling across interfaces. Nevertheless, known exchange springs in oxides are yet scarce [1], since the unambiguous identification is not straightforward. An intensely studied model system for strong interface coupling is $SrRuO_3/La_{0.7}Sr_{0.3}MnO_3$ coherently grown on $SrTiO_3(001)$ substrate. We summarize here the characteristics and suggested origin of the Bloch-type exchange spring forming at this interface in bilayers grown by pulsed laser deposition. Strikingly, the spring forms in hard-magnetic $SrRuO_3$ where magnetic anisotropy is suppressed within few unit cells from the interface. We suggest the transfer of oxygen octahedra rotations / tilts to be responsible, a structural coupling mechanism occurring at many other coherent oxide interfaces. Implications of the noncollinear spin configuration for spintronic functionalities will be addressed.

[1] A. M. Kane, Phys. Rev. Mater. 3, 014413 (2019)

MA 17.5 Tue 10:30 POT 6

Characterization of buffer-free $Sm(Co_{5-x}Cu_x)_5$ thin films grown by molecular beam epitaxy — •Georgia Gkouzia[1], Damian Günzing[2], Teresa Wessels[2,3], Marton Major[1], Alpha T. N Diaye[4], Andras Kovacs[3], Heiko Wende[2], Katharina Ollefs[2], and Lambert Alff[1] — [1]Technical University of Darmstadt, Materials Science, Darmstadt, Germany — [2]University of Duisburg-Essen, Faculty of Physics and Center for Nanointegration, Duisburg, Germany — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Gruenberg Institute, Forschungszentrum Juelich, Germany — [4]Lawrence Berkeley National Laboratory, Berkeley, USA

$SmCo_5$ permanent magnets were already known in the 60s due to their enormous uniaxial magnetic anisotropy K1=17.2 MJ/m^3 which has made them key materials for many applications. Sm-Co system, in a certain parameter range, undergoes a phase decomposition into a nanocomposite of $SmCo_5$ and Sm_2Co_{17} phases. Since it is known that Cu stabilizes the $SmCo_5$ phase, in this work, buffer-free $Sm(Co_{5-x}Cu_x)_5$ thin films have been grown by molecular beam epitaxy (MBE). The films have been characterized by x-ray diffraction (XRD), superconducting quantum interference device (SQUID), and transition electron microscopy (TEM). High coercivity, 1.67 T has been achieved, among the largest values for buffer-free $SmCo_5$ films. X-ray magnetic circular dichroism (XMCD) element-specific hysteresis loops show clear evidence of the Sm-Co de-coupled moments due to Cu substitution in the Co-sublattice.

MA 17.6 Tue 10:45 POT 6

Europium oxide: Growth guide for the first monolayers on oxidic substrates — •Paul Rosenberger[1,2] and Martina Müller[2] — [1]Fakultät Physik, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

Interfacial oxygen exchange at oxide interfaces bears huge potential in stabilizing metastable or novel phases of functional oxides down to the monolayer limit. Consequently, controlling the underlying interfacial processes opens up the possibility to tailor and tune functionalities of oxide interfaces. By taking advantage of active oxygen supply of the substrate material, waiving any external oxygen dosage, high-quality, crystalline ultrathin films of the Heisenberg ferromagnet europium monoxide (EuO) were stabilized on YSZ (001)[1]. This so-called redox-assisted growth mode was monitored end to end by in situ x-ray photoelectron spectroscopy. The evolution of Eu 3d core levels allows us to disentangle the processes of interfacial oxygen diffusion and vacancy formation in stabilizing the very first monolayers of EuO on YSZ (001). An expedient background correction analysis is presented, which allows us to quantify the critical Eu^{3+}/Eu^{2+} ratio in the ultrathin film regime. We concluded on the key mechanisms of redox-assisted EuO/YSZ (001) thin film synthesis, merging in a universal three-process growth model that may serve as guideline for

redox-assisted synthesis of metastable low-dimensional oxides.
[1] P. Rosenberger and M. Müller, Phys. Rev. Mater. 6, 044404 (2022).

MA 18: Functional Antiferromagnetism I

Time: Tuesday 15:00–17:15 Location: HSZ 02

MA 18.1 Tue 15:00 HSZ 02

Magnetization dynamics in hybrid $Mn_2Au/Ni_{80}Fe_{20}$ system — •Hassan Al-Hamdo[1], Tobias Wagner[2], Yaryna Lytvynenko[2], Gutenberg Kendzo[1], Sonka Reimers[2], Moritz Ruhwedel[1], Misbah Yaqoob[1], Philipp Pirro[1], Olena Gomonay[2], Vitaliy I. Vasyuchka[1], Mathias Kläui[2], Martin Jourdan[2], and Mathias Weiler[1] — [1]Fachbereich Physik und Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

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].Furthermore, Mn_2Au enables current pulse induced switching of the Néel vector via Néel spin-orbit torques [2] making this system intriguing for antiferromagnetic spintronics. By varying the thickness of the ferromagnetic layer, we investigated the effect of strongly exchange coupled $Mn_2Au/Ni_{80}Fe_{20}$ interface on the spin dynamics. Broadband ferromagnetic resonance and Brillion light scattering experiments reveal that interfacial exchange coupling causes an increase in the resonance frequency of $Ni_{80}Fe_{20}$. Our theoretical model based on the modification of the spin-wave wavevector due to interfacial coupling yields good agreement with the experimental observations.

[1] Bommanaboyena et al., Nature Communications **12**, 6539 (2021) [2] Y. Lytvynenko et al., arXiv:2208.04048v1 (2022).

MA 18.2 Tue 15:15 HSZ 02

Magnetization dynamics in hybrid ferromagnetic / antiferromagnetic systems — •Tobias Wagner[1], Hassan Al-Hamdo[2], Mathias Weiler[2], and Olena Gomonay[1] — [1]Institut für Physik, JGU Mainz, Germany — [2]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern, Germany

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 $Mn_2Au/Ni_{80}Fe_{20}$ was reported to be 0.5 T, which is high compared to 0.02 T in CuMnAs/Fe [2]. Due to strong exchange coupling, the AFM Néel vector and the ferromagnetic (FM) magnetisation rotate coherently, when an external field is applied to the FM. Control of the Néel ordered state in Mn_2Au and the $Ni_{80}Fe_{20}$ spin dynamics has been studied by varying the $Ni_{80}Fe_{20}$ layer thickness [3]. Ferromagnetic resonance spectroscopy revealed two distinct frequencies for the coupled bilayer system, both of which lie above the resonance frequency of Permalloy [3]. We calculate the spectra of the magnons in the coupled FM/AFM system within micromagnetic 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. We estimate the exchange coupling strength to be 5 T [3]. References: [1] Bommanaboyena, S. P. et al., Nat. Comm. 12, 6539 (2021), [2] Wadley, P. et al., Sci. Rep. 7, 11147 (2017), [3] Al-Hamdo, H. et al., unpublished.

MA 18.3 Tue 15:30 HSZ 02

Optically Triggered Néel Vector Manipulation of a Metallic Antiferromagnet Mn_2Au under Strain — Vladimir Grigorev[1], Mariia Filianina[1], Yaryna Lytvynenko[1], Sergei Sobolev[1], Amrit Raj Pokharel[1], •Amon P. Lanz[1], Alexey Sapozhnik[2], Armin Kleibert[3], Stanislav Bodnar[4], Petr Grigorev[5], Yurii Skourski[6], Mathias Kläui[1], Hans-Joachim Elmers[1], Martin Jourdan[1], and Jure Demsar[1] — [1]JGU, Mainz, Germany — [2]École Polytechnique, Lausanne, Switzerland — [3]PSI, Villingen, Switzerland — [4]TUM, Munich, Germany — [5]Aix-Marseille Université, Marseille, France — [6]HZDR, Dresden, Germany

The absence of stray fields, their insensitivity to external magnetic fields, and ultrafast dynamics make antiferromagnets promising candidates for active elements in spintronic devices. Here, we demonstrate manipulation of the Néel vector in the metallic collinear antiferromagnet Mn_2Au by combining strain and femtosecond laser excitation. Applying tensile strain along either of the two in-plane easy axes and locally exciting the sample by a train of femtosecond pulses, we align the Néel vector along the direction controlled by the applied strain. The dependence on the laser fluence and strain suggests the alignment is a result of optically triggered depinning of 90° domain walls and their motion in the direction of the free energy gradient, governed by the magneto-elastic coupling. The resulting, switchable state is stable at room temperature and insensitive to magnetic fields. Such an approach may provide ways to realize robust high-density memory device with switching time scales in the picosecond range.

MA 18.4 Tue 15:45 HSZ 02

Long-distance magnon spin transport in Orthoferrites. — •E.F. Galindez-Ruales[1], S. Das[1], X. X. Ma[2], G. Jakob[1], S. X. Cao[2], R. Lebrun[3], and M. Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, 55128 Mainz, Germany. — [2]Department of Physics, Materials Genome Institute, International Center for Quantum and Molecular Structures, Shanghai University, Shanghai 200444, China. — [3]Unité Mixte de Physique CNRS, Thales, Université Paris-Saclay, Palaiseau 91767, France.

Antiferromagnets have advantages over ferromagnets, such as terahertz-range magnetization dynamics and stability against external magnetic fields. The efficient transport of spin waves has until now only been observed in the insulating antiferromagnet hematite [1]. In this work [2], we report long-distance spin transport in the antiferromagnetic orthoferrite $YFeO_3$; although the magnetic damping order is in the same range as hematite, the spin transport is different. At zero magnetic field, the magnon modes in $YFeO_3$ are linearly polarized, which cannot transport the spin angular momentum. Nevertheless, under an external magnetic field and the presence of DMI, spin information is carried by elliptically polarized modes. We observe a strong anisotropy in the magnon decay lengths that we attributed to the role of the magnon group velocity in the transport of spin waves in antiferromagnets. This unique mode of transport identified in $YFeO_3$ opens up all the canted antiferromagnets for long-distance spin transport. [1] Lebrun, R., et al. Nat Commun. 11, 6332 (2020). [2] Das, S., et al. Nat. Commun. 13, 6140 (2022).

15 min. break

MA 18.5 Tue 16:15 HSZ 02

Coexistence of antiferromagnetism and ferrimagnetism in adjacent honeycomb layers — •Lilian Prodan[1,2], Viorel Felea[1,2,3], Yurii Skourskii[3], Sergei Zherlitsyn[3], Joachim Wosnitza[3], Alexander Tsirlin[4], Vladimir Tsurkan[1,2], and István Kezsmarki[1] — [1]Experimental Physics V, Institute of Physics, University of Augsburg, D-86159, Augsburg, Germany — [2]Institute of Applied Physics, MD 2028, Chisinau, R. Moldova — [3]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, 01328 Dresden, Germany — [4]Felix Bloch Institute for Solid-State Physics, Leipzig University, 04103 Leipzig, Germany

Recent theoretical and experimental studies of the honeycomb antiferromagnets $A_2Mo_3O_8$ (A = Mn, Fe, Co, Ni, Zn) revealed a plethora of fascinating effects, such as strong linear and non-linear magnetoelectric effects, giant magnetoelectricity, hidden ferromagnetism, and topological magnons, being of interest for both fundamental and applied research. Here, we report a sequence of metamagnetic transitions in the polar antiferromagnet $Co_2Mo_3O_8$ based on magnetization, torque and ultrasound measurements in static and pulsed magnetic fields up to 65 T. Our studies reveal a novel spin state that is composed of an alternating stacking of antiferromagnetic and ferrimagnetic honeycomb layers. The strong intra-layer and the weak inter-layer exchange couplings together with competing anisotropies at octahedral and tetrahedral Co sites are identified as the key ingredients to stabilize antiferromagnetic and ferrimagnetic layers in such a close proximity [1]. [1]. D. Szaller et al., arXiv:2202.04700 (2022).

MA 18.6 Tue 16:30 HSZ 02

Anisotropic effects in antiferromagnetic curvilinear spin chains — •Oleksandr V. Pylypovskyi[1,2], Yelyzaveta A. Borysenko[3], Denys Y. Kononenko[4], Kostiantyn V. Yershov[4], Ulrich K. Roessler[4], Artem V. Tomilo[1,3], Jeroen van den Brink[4], Jürgen Fassbender[1], Denis D. Sheka[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Kyiv Academic University, 03142 Kyiv, Ukraine — [3]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine — [4]IFW Dresden, 01069 Dresden, Germany

Curvilinear spin chains are simplest antiferromagnetic systems revealing direct influence of their shape onto magnetic states via geometry-tracking anisotropies stemming from the dipolar interaction [1] or local surrounding [2]. Here, we show that in addition to the strongest effect onto magnetic state from exchange (biaxial anisotropy and chiral energy term) [1], the local break of the translational symmetry in curvilinear antiferromagnets leads to (i) the longitudinal Dzyaloshinskii-Moriya energy term stemming from the single-ion anisotropy and (ii) the local weakly ferromagnetic response [2]. Furthermore, non-zero curvature κ can drive the helimagnetic phase transition in the spin-flop phase and enables the intermediate canted state for rings with large enough κ. [1] O. Pylypovskyi, D. Kononenko et al., Nano Lett. 20, 8157 (2020); [2] O. Pylypovskyi et al., Appl. Phys. Lett. 118, 182405 (2021); [3] Y. Borysenko et al., Phys. Rev. B, 106, 174426 (2022).

MA 18.7 Tue 16:45 HSZ 02

Spin-current driven Dzyaloshinskii-Moriya interaction in the multiferroic BiFeO3 from first-principles — •Sebastian Meyer[1], Bin Xu[2,3], Matthieu J. Verstraete[1], Laurent Bellaiche[3], and Bertrand Dupé[1,4] — [1]Université de Liège, Belgium — [2]Soochow University, China — [3]University of Arkansas, USA — [4]Fonds de la Recherche Scientifique (FRS-FNRS), Belgium

The electrical control of magnons opens up new ways to transport and process information for logic devices. In magnetoelectrical multiferroics, the Dzyaloshinskii-Moriya (DM) interaction directly allow for such a control and, hence, is of major importance [1]. We determine the origin and strength of the (converse) spin current DM interaction [2,3] in the $R3c$ bulk phase of the multiferroic $BiFeO_3$ based on density functional theory. Our data supports only the existence of one DM interaction contribution originating from the spin current model. By exploring the magnon dispersion in the full Brillouin Zone, we show that the exchange is isotropic, but the DM interaction and anisotropy prefer any propagation and magnetization direction within the full (111) plane. Our work emphasizes the significance of the asymmetric potential induced by the spin current over the structural asymmetry induced by the anionic octahedron in multiferroics such as $BiFeO_3$.

[1] P. Rovillain, *et. al.*, Nature Materials **9**, 975 (2010)
[2] H. Katsura, *et. al.*, Phys. Rev. Lett. **95**, 057205 (2005)
[3] D. Rahmedov, *et. al.*, Phys. Rev. Lett. **109**, 037207 (2012)

MA 18.8 Tue 17:00 HSZ 02

Decoding Antiferromagnetism via Quadrupolar Far Fields — •Michael Paulsen[1], Michael Fechner[2], Julian Lindner[3], Ralf Feyerherm[3], Jörn Beyer[1], Bastian Klemke[3], Yuki Lino[4], Tsuyoshi Kimura[5], Klaus Kiefer[3], and Dennis Meier[6,7] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [4]Division of Materials Physics, Osaka University, Japan — [5]Department of Advanced Materials Science, University of Tokyo, Japan — [6]Department of Materials Science and Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway — [7]Center for Quantum Spintronics, NTNU, Trondheim, Norway

Antiferromagnets possess zero net dipole magnetization, whereas magnetic higher-order contributions are, in principle, allowed by symmetry. Such higher-order contributions are, however, usually extremely weak and hard to detect experimentally. Here, we present low-temperature magnetometry measurements of the higher-order far fields of the antiferromagnetic model systems Cr_2O_3 and $TbMnO_3$, using a dedicated SQUID setup. Our results reveal exterior quadrupolar magnetic fields specific to the emergent microscopic spin textures, providing new opportunities for the characterization of antiferromagnets and materials with ultra-small remanent magnetization in general.

MA 19: Molecular Magnetism I

Time: Tuesday 15:00–17:00 Location: HSZ 04

MA 19.1 Tue 15:00 HSZ 04

Molecular orientation of Er(III) cyclooctatetraene-based single-molecule magnets on Ag(100) — •Vladyslav Romankov[1], Niéli Daffé[1], Diana Vaclavkova[1], Martin Heinrich[1], Matthias Muntwiler[1], Bernard Delley[1], Katie Harriman[2], Muralee Murugesu[2], Moritz Bernhardt[3], Maciej Korzyński[3], Christophe Copéret[3], and Jan Dreiser[1] — [1]PSI, Switzerland — [2]uOttawa, Canada — [3]ETH Zurich, Switzerland

Recently, organometallic lanthanide-(III)-based single-molecule magnets (SMMs) have shown outstanding magnetic properties up to liquid nitrogen temperature [1]. SMMs with planar ligands, like COT^{2-} (cyclooctatetraene anion) and Cp^{*-} (pentamethylcyclopentadienide), are good candidates to form ordered monolayers, but the packing and the molecule-substrate interaction play a vital role in the properties of such molecules when deposited on metal surfaces [2]. In the present work we show how two similar Er(III) SMMs, $K[Er(COT)_2]$ and Cp*ErCOT, order very differently on Ag(100). In particular, X-ray linear and magnetic circular dichroism measurements show that the easy axis of $K[Er(COT)_2]$ aligns parallel to the surface, while that of Cp*ErCOT SMMs is consistent with a mixed standing-lying phase. Indeed, low-temperature scanning tunneling microscopy reveals that Cp*ErCOT forms alternating rows of standing-up and lying-down molecules, while X-ray photoemission spectroscopy reveals the integrity of both the SMMs and suggests a weak molecule-surface interaction.

References: [1] F. S. Guo et al., Science, **362**, 1400, (2018); [2] C. Wäckerlin et al., Advanced Materials, **28**, 5142, (2016).

MA 19.2 Tue 15:15 HSZ 04

Machine learning based parameterization of magnetic data of single-molecule magnets — •Zayan Ahsan Ali, Julius Mutschler, and Oliver Waldmann — Physikalisches Institut, Universität Freiburg, D-79104 Freiburg, Germany

Single molecule magnets (SMMs) have attracted a rich volume of research in the last two decades due to their potential applications in magnetic memory and quantum computing. Lanthanide-based SMMs in particular demonstrate promising magnetic retention due to large inherent anisotropies. Their magnetic properties can be parameterized by ligand-field theories involving a set of 28 parameters. Experimental data such as magnetization and susceptibility curves, however, are typically featureless for these materials. Multiple distinct parameter sets can describe the data to equal accuracy, making it a formidable task to determine the model parameters for a compound. In this work, the over-parameterization is tackled by Machine Learning (ML) applied to data simulated for a single-ion model. For dimensionality reduction, a variational autoencoder is used to determine hidden system parameters of the data, and an invertible neural network is used to relate hidden parameters with the model parameters from ligand-field theory. The effectiveness of this ML model in producing consistent sets of ligand-field parameters for novel experimental data is investigated and presented.

MA 19.3 Tue 15:30 HSZ 04

Temperature-dependent Raman spectroscopy studies of a Fe(II) spin-crossover complex — •Lea Spieker[1], Stephan Sleziona[1], Gérald Kämmerer[1], André Maas[1], Soma Salamon[1], Senthil Kumar Kuppusamy[2], Mario Ruben[2], Uwe Bovensiepen[1], Peter Kratzer[1], Marika Schleberger[1], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute of Quantum Materials and Technologies (IQMT), Karlsruhe Institute of Technology

Spin-crossover complexes with a bi-stable spin-state switching in the room temperature regime, influenced by external stimuli such as light, pressure, or temperature, are desirable for future applications, e.g., molecular switches. Combining Raman spectroscopy with optical microscopy, we investigated a Fe(II) complex showing a spin-state switching from a diamagnetic low-spin (S=0) to a paramagnetic high-spin (S=2) state in the room temperature regime ($T_{1/2} = 298\,\mathrm{K}$) with a broad thermal hysteresis of $\Delta T = 44\,\mathrm{K}$. Notable molecular bond changes during the temperature-induced spin-state switching are confirmed by Raman spectroscopy measurements combined with density functional theory calculations. In addition, optical microscopy during heating and cooling allowed us to observe the spin-state switching on a macroscopic scale. We gratefully acknowledge the financial support by CRC 1242 Projects A05, B02, and C05 (Project-ID 278162697).

MA 19.4 Tue 15:45 HSZ 04

Spin transition of spin-crossover molecules supported by tridentate ligands deposited on HOPG — •Jorge Torres[1], Jan Grunwald[2], Sascha Ossinger[2], Sangeeta Thakur[1], Clara W. A. Trommer[2], Marcel Walter[1], Ivar Kumberg[1], Rahil Hosseinifar[1], Evangelos Golias[1], Sebastien Hadjaj[1], Jendrik Gördes[1], Pin-Chi Liu[1], Chen Luo[3], Lalminthang Kipgen[1], Tauquir 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 a spin-crossover molecule (SCM) the excitation and relaxation processes can be stimulated by temperature, pressure or light. The latter is known as the light-induced excited spin-state trapping (LIESST) effect. The excitation of the high-spin (HS) and relaxation to low-spin (LS) state can exhibit single- or multi-exponential behavior. Here, we investigate the behavior of different thicknesses of the SCM [Fe{H_2B(pz)(pypz)}$_2$] [1] and [Fe{pypypyr}$_2$] deposited on highly oriented pyrolytic graphite (HOPG) by X-ray absorption and differential reflectance spectroscopy. The results show that the amount of molecules in the HS state as a function of temperature at constant illumination presents a sigmoidal behavior. The relaxation rates are discussed in the context of the inverse energy gap law, which is usually invoked to interpret the LIESST behaviour of Fe(II) complexes.

[1] S. Ossinger et al., Inorg. Chem., 2020, 59, 7966-7979

15 min. break

MA 19.5 Tue 16:15 HSZ 04

Observation of exchange interaction in Iron(II) spin crossover molecules in contact with passivated ferromagnetic surface of Co/Au(111) — •hongyan chen[1], hung-hsiang yang[1], timo frauhammer[1], haoran you[1], qing sun[2], peter nagel[3,4], stefan schuppler[3,4], ana belén gaspar[5], josé antonio real[5], and wulf wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Germany — [2]Laboratory for Electron Microscopy, KIT — [3]Institute for Quantum Materials and Technologies, KIT — [4]Karlsruhe Nano Micro Facility, KIT — [5]Institut de Ciència Molecular, Universitat de València, Spain

Spin crossover (SCO) complexes sensitively react on changes of the environment by a change in the spin of the central metallic ion making them ideal candidates for molecular spintronics. In particular, the composite of SCO complexes and ferromagnetic (FM) surfaces would allow spin-state switching of the molecules in combination with the magnetic exchange interaction to the magnetic substrate. Unfortunately, when depositing SCO complexes on ferromagnetic surfaces, spin-state switching is blocked by the relatively strong interaction between the adsorbed molecules and the surface. Here, the Fe(II) SCO complex with sub-monolayer (sub-ML) thickness in contact with a passivated FM film of Co on Au(111) is studied. In this case, the molecules preserve thermal spin crossover and at the same time the high-spin species show a sizable exchange interaction of more than 0.7 T with the FM Co substrate. These observations provide a feasible design strategy in fabricating SCO-FM hybrid devices.

MA 19.6 Tue 16:30 HSZ 04

Magnetic coupling of guest metallocene molecules with SURMOF-2 host matrix — •Alexei Nefedov[1], Chun Li[1], Kai Müller[1], Anemar Bruno Kanj[1], Lars Heinke[1], Chen Luo[2], Kai Chen[2], Florin Radu[2], Evangelos Golias[3], Wolfgang Kuch[3], and Christof Wöll[1] — [1]Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]Freie Universität Berlin, Berlin, Germany

Metal-organic frameworks (MOFs) are crystalline and porous, molecular solids consisting of metal nodes and organic ligands. In the case of surface-anchored MOF-2 (SURMOF-2) systems the Cu^{2+} ions are connected via carboxylate and OH groups in a zipper-like fashion. This unusual coupling of the spin-1/2 ions within the resulting 1-D chains stabilizes a low-temperature ferromagnetic (FM) phase. In this study, the magnetic properties of SURMOF-2 systems (Cu(bdc) and Cu(bpdc)) were investigated using X-ray magnetic circular dichroism both in the absorption and in the scattering geometry. Taking advantage of the element sensitivity of this technique it was established that the magnetic signal originates from Cu^{2+} ions. After loading of SURMOF-2 with metallocene molecules, the magnetic properties of the SURMOF were found to be substantially changed. In the case of nickelocene loading, a polarization effect was found resulting in ferromagnetic ordering of the guest molecules. However, the polarization effect is not observed in the case of manganocene derivatives, these molecules remained in their paramagnetic state.

MA 19.7 Tue 16:45 HSZ 04

Nickelocene molecule as an STM magnetic sensor — •Andres Pinar Sole[1], Oleksandr Stetsovych[1], Pavel Jelínek[1], Jindrich Kolorenc[1], Shaotang Song[2], Jiong Lu[2], Christian Wackerlin[3], and Ales Cahlik[4] — [1]Czech Institute of Physics — [2]University of Singapore — [3]Empa — [4]University of Zurich

Functionalization of the scanning probe of a scanning tunnelling microscopy (STM) with metallocene molecule allows performing spin-sensitive measurements on magnetic systems. Here, as a magnetic sensor, we used a nickelocene molecule (NiCp2) to probe the magnetism on 1D metallorganic chains and graphene nanoribbons (GNR).

In the first part of the work, we examined two derivatives of 1D metallorganic coordination polymers (2,5-diamino-1,4-benzoquinonediimines) on Au(111) [3] with Co or Cr atoms as metal sites respectively. Nickelocene IETS conductance spectrum deformation was observed when approaching the Nc functionalized tip to the Cr sites while no spectra changes were seen on neither Co sites nor ligand sites of the polymers.

In the second part of the work, the Nc functionalized probe was also used to measure the magnetism emerging from the unpaired electron on the edge of a wave-like graphene nanoribbon (GNR) on Au(111).

To understand the IETS from the magnetic sensor, a many-body Hubbard model was proposed. It describes the electron tunnelling through the STM tip, the nickelocene, the magnetic center, and the metallic substrate.

MA 20: Spintronics (other effects)

Time: Tuesday 15:00–17:45 Location: HSZ 401

MA 20.1 Tue 15:00 HSZ 401

Ab initio studies of chiral crystals for generalized linear response transport and x-ray absorption spectroscopy — •Alberto Marmodoro[1], Hubert Ebert[2], and Ondrej Sipr[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 20.2 Tue 15:15 HSZ 401

Crystallisation behaviour of Yttrium Iron Garnet thin films — •Sebastian Sailler[1], Michaela Lammel[1], Gregor Skobjin[1], Heike Schlörb[2], Andy Thomas[2,3], and Sebastian T.B. Goennenwein[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Institute for Integrative Nanosciences, Leibniz Institute of Solid State and Materials Science, 01069 Dresden, Germany — [3]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01069 Dresden, Germany

Yttrium Iron Garnet (YIG) is a ferrimagnetic insulator commonly used in spin transport and spin dynamics. To obtain highly crystalline thin films we use RF-magnetron sputtering at room temperature to deposit amorphous films and a subsequent annealing step to crystallise them. However, the crystallisation from the amorphous state has not been systematically studied. We therefore analyse the crystallisation behaviour on different substrates utilizing extensive time and temperature series. Structural characterisation using X-ray techniques as well as electron diffraction allow to differentiate between amorphous, polycrystalline and epitaxial films, and to determine the optimal annealing parameters for each substrate. Additionally, we correlate the crystalline state with the resulting magnetic properties inferred from magnetometry and Kerr-microscopy. Our results provide a precise tunability of the structural and magnetic properties of YIG by a rigorous control over the crystallization induced by the subsequent annealing step.

MA 20.3 Tue 15:30 HSZ 401

Excited-state exchange interaction in NiO determined by high-resolution resonant inelastic x-ray scattering at the Ni $M_{2,3}$ edges — •Chun-Yu Liu[1,2], Kari Ruotsalainen[1], Karl Bauer[1], Régis Decker[1], Annette Pietzsch[1], and Alexander Föhlisch[1,2] — [1]Institute for Methods and Instrumentation for Synchrotron Radiation Research (PS-ISRR), Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB), Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Strasse 24-25, 14476 Potsdam, Germany

The electronic and spin excitations of bulk NiO have been determined using the $^3A_{2g}$ to $^3T_{2g}$ crystal-field transition at the Ni $M_{2,3}$ edges with high resolution resonant inelastic x-ray scattering. We extract an effective exchange field of 89±4 meV in the $^3T_{2g}$ excited final state from empirical two-peak spin-flip model, which is further confirmed with crystal-field model calculations using exchange fields of 60-100 meV. The lower exchange parameter in the excited state is discussed in terms of the modification of the orbital occupancy and of the structural dynamics: (A) With pure electronic effects, the lower exchange energy is attributed to the reduction in effective hopping integral. (B) With no electronic effects, we use the S = 1 Heisenberg model to derive a second-nearest-neighbor exchange constant $J_2 = 14.8\pm0.6$ meV. Based on the linear correlation between J_2 and the lattice parameter from pressure-dependent experiments, an upper limit of 2% local Ni-O bond elongation during the fs scattering duration is derived.

MA 20.4 Tue 15:45 HSZ 401

Strongly coupled magnon-plasmon polaritons in graphene-2D ferromagnet heterostructures — •António Costa[1], Mikhail Vasilevskiy[1,2], Joaquín Fernández-Rossier[1], and Nuno Peres[1,2] — [1]International Iberian Nanotechnology Laboratory (INL) — [2]Department of Physics, Center of Physics, University of Minho

Magnons and plasmons are two very different types of collective modes, acting on the spin and charge degrees of freedom, respectively. At first sight, the formation of hybrid plasmon-magnon polaritons in heterostructures of plasmonic and magnetic systems would face two challenges, the small mutual interaction, via Zeeman coupling of the electromagnetic field of the plasmon with the spins, and the energy mismatch, as in most systems plasmons have energies in the eV range, orders of magnitude larger than magnons. Here we show that graphene plasmons form polaritons with the magnons of two-dimensional ferromagnetic insulators, placed up to to half a micron apart, with Rabi couplings in the range of 100 GHz (dramatically larger than cavity QED magnonics). This strong coupling is facilitated both by the small energy of graphene plasmons and the cooperative super-radiant nature of the plasmon-magnon coupling afforded by phase matching. We show that the Rabi coupling can be modulated both electrically and mechanically and we propose an attenuated total internal reflection experiment to implement ferromagnetic resonance experiments on 2D ferromagnets driven by plasmon excitation.

MA 20.5 Tue 16:00 HSZ 401

Doping induced ferromagnetism in EuTiO3 and STO/ETO/LAO heterostructures by ab-initio calculations — •Payal Wadhwa and Alessio Filippetti — Department of Physics, University of Cagliari, Sardinia, Italy

The emergence of 2DEG at oxide interfaces such as LaAlO3 (LAO) and SrTiO3 (STO) raised an immense interest in the community of oxide electronics, because of depicting outstanding properties such as field-effect driven superconductivity, high electron mobility, and magnetoresistance. An old dream of the spintronic community, remained eluded so far, has been to spin-polarize the 2DEG by introducing a magnetic layer at the interface of LAO/STO heterostructure, which may enable it to be a paramount material for spintronics and spin-orbitronic technology. A potential candidate as magnetic interlayer is EuTiO3 (ETO), having an identical lattice constant to STO. It is reported that ETO possesses G-type AFM ground state below Tn = 5.3 K, while becomes FM under tensile strain or doping. We have employed an ab-initio approach to study structural, electronic, and magnetic properties of ETO bulk and the STO/ETO/LAO heterostructure. We found, for increasing electron doping, a progressive enhancement of the FM phase in bulk ETO. Since conduction electrons can also be added to the ETO by creating a heterointerface, so we also compared the n-doped bulk ETO results with the STO/ETO/LAO heterostructure. Overall, our results for n-doped ETO and STO/ETO/LAO heterostructure depict them to be potential candidates for electronic transport and magneto-transport applications.

15 min. break

MA 20.6 Tue 16:30 HSZ 401

Magnetism and proximity-induced Rashba effect at Mn-3*d* bands of asymmetric $BaMnO_3|KTaO_3$ heterojunction — •Vivek Kumar and Nirmal Ganguli — Indian Institute of Science Education and Research Bhopal, Bhauri, Bhopal 462066, India

Rashba-like spin-orbit interaction (SOI) at oxide heterostructures emerges as a much sought-after feature in the context of oxide spintronics and spin-orbitronics. $KTaO_3$ (KTO) is one of the best substrates available for the purpose, owing to its strong SOI and alternating $+1|-1$ charged layers along the (001) direction. We visualize the Rashba-like interaction in the KTO (001) surface with the help of spin texture plotted directly from DFT calculations along with the isoenergetic contours, providing a confirmatory test of the presence of only linear Rashba interaction [1]. We use *ab initio* DFT to examine the asymmetric $BaMnO_3|KTaO_3$ (BMO|KTO) oxide heterostructure where the inequivalent bottom and top interfaces break the inversion symmetry due to their opposite polar discontinuities. We observe Rashba-like splitting for the bands of Mn-3*d* near the Fermi level of *C*-type antiferromagnetic (AFM) BMO|KTO owing to the proximity to Ta atoms from the 5*d* series. We comprehensively analyze Rashba-like SOI with the help of three-dimensional band dispersion and projected spin textures for Rashba-like Mn-3*d* bands. Our results reveal reasonably strong linear Rashba interaction in the heterostructure. The rigorous analysis of spin textures of the AFM heterostructure presented here may be crucial for spintronics. [1] V. Kumar and N. Ganguli, Phys. Rev. B 106, 125127 (2022).

MA 20.7 Tue 16:45 HSZ 401

Spin-mixing states at finite temperature — •Danny Thonig[1,2], Simon Streib[2], Ramon Cardias[3], Sumanta Bhandary[4], Yaroslav Kvashnin[2], and Olle Eriksson[2,1] — [1]Örebro University, Sweden — [2]University Uppsala, Sweden — [3]KTH Royal Institute of Technology, Sweden — [4]Trinity College Dublin, The University of Dublin, Ireland

In spintronics, the electron spins are used as information carriers and, thus, the description of spin relaxation is of fundamental relevance. Spin relaxation characterises how rapidly the non-equilibrium spin population decays due to spin mixing [1], which wise versa depends on the magnetic moment length and on the temperature simulated by disorder acting on the magnetic state. But the latter phenomenons is barely understood.

We quantify the presence of spin-mixed states in spin and lattice disordered magnetic 3d transition metals by calculating the Elliot-Yafet spin-mixing parameter b^2. Here, we are using a self-consistent, relativistic, Slater-Koster parametrized tight-binding electronic structure model.

We, first, compare our results of the collinear order in itinerant magnets with density functional theory calculations and experiment. After, we analyse b^2 at finite temperature, finding a drastic increase by a factor > 10. This can be understood since both spin orbit coupling and disorder have a similar impact on the electronic potential [2].

[1] D. Steiauf et al., *Phys. Rev. B* **79** 140401 (2009)
[2] L. Nordström et al., *Phys. Rev. Lett.* **76** 4420 (1996)

MA 20.8 Tue 17:00 HSZ 401

Spin-caloritronics using spin-polarized scanning tunneling microscopy — •Cody Friesen and Roland Wiesendanger — Department of Physics, University of Hamburg, Hamburg, Germany

The study and control of magneto- and thermoelectric effects have long been of fundamental importance, from the perspectives of both basic condensed matter research and technological development. More recently, driven by the discovery of the spin-Seebeck effect, a growing amount of research is being done at the intersection of these transport channels; a field known as spin-caloritronics [1]. The possible applications of these effects, e.g. the efficient conversion of waste heat into spin or charge currents, or the magnetic control of heat transfer on the atomic scale, have far-reaching implications for future technology.

Using spin-polarized scanning tunneling microscope (SP-STM) we have investigated magneto-Seebeck tunneling, i.e. the spin-dependent tunneling of electrons across a magnetic tunnel junction driven by a temperature gradient [2]. By scanning a (relatively) heated magnetic probe tip in tunneling contact with a magnetic sample, at cryogenic temperatures the spin-resolved thermopower of the junction can be resolved with atomic-scale lateral resolution [3,4].

In this talk I will present the experimental requirements, challenges, and advantages of using SP-STM for studies of spin-caloritronics. Following this, the expansion of this approach to the measurement of thermal spin-transfer torque, as well as further development of SP-STM as a tool for spin-caloritronic studies, will be discussed.

MA 20.9 Tue 17:15 HSZ 401

Fractional Landau-Lifshitz-Gilbert equation — Robin C. Verstraten[1], •Tim Ludwig[1], Rembert A. Duine[1,2], and Cristiane Morais Smith[1] — [1]Institute for Theoretical Physics, Utrecht University, Princetonplein 5, 3584CC Utrecht, The Netherlands — [2]Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Gaining a deeper understanding of magnetization or spin dynamics is of great interest to improve modern technological devices. In particular, a deeper understanding of dissipation could help to improve device efficiency. Magnetization dynamics is often described by the Landau-Lifshitz-Gilbert equation with phenomenological Gilbert damping. Using the Caldeira-Leggett approach, we can re-derive Gilbert damping for a specific type of environment (Ohmic) but, in general, we find fractional Gilbert damping. Fractional Gilbert damping is similar to Gilbert damping but the time derivative is replaced by a fractional time derivative. Finally, we discuss experimental consequences of fractional Gilbert damping with a focus on ferromagnetic resonance experiments.

MA 20.10 Tue 17:30 HSZ 401

Driving a magnetic texture by magnon currents — •Michael Vogel[1,2], Bernhard Zimmermann[1], Johannes Wild[1], Felix Schwarzhuber[1], Claudia Mewes[3], Tim Mewes[3], Josef Zweck[1], and Christian H. Back[1,4] — [1]Department of Physics, Regensburg University, Regensburg, Germany — [2]Institute for Materials Science, Kiel University, Kiel, Germany — [3]Department of Physics and Astronomy, The University of Alabama, Tuscaloosa, USA — [4]Department of Physics, Technical University Munic, Munich, Germany

Thermally-induced spin dynamics in solids have sparked broad interest in both fundamental physics and spintronic applications. As theoretically proposed, thermally excited magnons created by temperature gradients can be used to manipulate spin textures such as topological magnetic solitons. However, in practice, the effectiveness of such thermomagnonic torques has remained a problem. Here the dynamics of magnetic vortex cores driven by thermomagnonic torques are explored by high-resolution Lorentz Transmission Electron Microscopy. Large deflections of the magnetic vortex core transverse to the direction of the temperature gradient are observed. The magnitude of the contribution of the associated torques is determined using a generalized Thiele equation model. Our findings pave the path for thermomagnonic currents to manipulate magnetic domains and shed light on the relationship between temperature and spin. The authors gratefully acknowledge financial support from the DFG within SpinCaT (SPP 1538) and the BMBF.

MA 21: Spin-Dependent Phenomena in 2D

Time: Tuesday 15:00–17:15 Location: HSZ 403

MA 21.1 Tue 15:00 HSZ 403

Material design of topological magnetism in 2D heterostructures — •Nihad AbuAwwad[1,2], Manuel dos Santos Dias[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]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

The discovery of two-dimensional (2D) van der Waals magnetic materials and their heterostructures provided an exciting platform for emerging phenomena with intriguing implications in information technology. $CrTe_2$ is a particular example that hosts complex magnetism strongly intertwined with its crystal structures [1,2]. Here, based on a multiscale modelling approach that combines first-principles calculations and a Heisenberg model, we demonstrate that interfacing this 2D layer with various Te-based layers hosting heavy or light elements enables the control of the Dzyaloshinskii-Moriya interaction and magnetic anisotropy energy of the whole heterostructure, and thereby the emergence of new magnetic phases of matter, which are of topological nature such as skyrmions and merons.
–Work funded by the Palestinian-German Science Bridge (BMBF–01DH16027) and Priority Programme SPP 2244 2D Materials Physics of van der Waals Heterostructures of the DFG (project LO 1659/7-1).
[1] AbuAwwad *et al.*, J. Phys.: Condens. Matter **34**, 454001(2022).
[2] Xian *et al.*, Nat. Commun. **13**, 257 (2022).

MA 21.2 Tue 15:15 HSZ 403

Tuning the magnetic interactions in van der Waals Fe_3GeTe_2 heterostructures — Dongzhe Li[1], •Soumyajyoti Haldar[2], Tim Drevelow[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

We investigate the impact of mechanical strain, stacking order, and external electric fields on the magnetic interactions of a Fe_3GeTe_2 monolayer deposited on Germanene using density functional theory [1]. We find that an electric field of $\mathcal{E} = \pm 0.5$ V/Å applied perpendicular to the Fe_3GeTe_2/germanene heterostructure leads to significant changes of the exchange constants. We show that the Dzyaloshinskii-Moriya interaction (DMI) in Fe_3GeTe_2/Germanene is mainly dominated by the nearest neighbors. Furthermore, we demonstrate that the DMI is highly tunable by strain, stacking, and electric field, leading to a large DMI comparable to that of ferromagnetic/heavy metal interfaces. The geometrical change and hybridization effect explain the origin of the high tunability of the DMI at the interface. The magnetocrystalline anisotropy energy (MAE) can also be drastically changed by the application of compressive or tensile strain. The tunability of DMI and MAE by using strain allows the occurrence of nanoscale skyrmions [2].

[1] D. Li, S. Haldar, T. Drevelow, S. Heinze, arXiv:2210.15351.
[2] D. Li, S. Haldar, S. Heinze, Nano Lett. **22**, 7706 (2022).

MA 21.3 Tue 15:30 HSZ 403

Spin-texture of graphene on Co films on heavy metals — •Donya Mazhjoo[1,2], Gustav Bihlmayer[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Physics Department, RWTH-Aachen University, 52062 Aachen, Germany

Graphene(Gr) covered ferromagnetic films deposited on heavy metals (HM) have been proposed for the exploration of novel spin-orbitronic devices since they possess a perpendicular magnetic anisotropy (MA) as well as a sizable Dzyaloshinskii-Moriya interaction (DMI). By using density functional theory as implemented in the Fleur-code [1], we investigate the spin-orbit (SO) induced spin-texture of Gr covered Co/Ir(111) heterostructures. We consider SOC in first order perturbation theory to study the DMI and self-consistently for the MA energy. Various thicknesses of Co are investigated and compared to experimental data. There, for thin Co films, spin- and angular-resolved photoemission spectroscopy found an in-plane spin-polarization of the Gr π bands, consistent with a HM induced Rashba-type SO coupling at the Gr/Co interface [2]. We compare to Pt(111) as HM substrate looking for signatures of the DMI in the (induced) spin-textures.
Support from the FLAG-ERA JTC 2019 grant SOgraphMEM is gratefully acknowledged.
[1] https://www.flapw.de
[2] B. Cano et al. arXiv:2206.04351

MA 21.4 Tue 15:45 HSZ 403

Magnetism and THz excitations in quasi-2D systems perturbed by external fields — •Karel Carva and Krishna K. Pokhrel — Charles University, Faculty of Mathematics and Physics, DCMP, Ke Karlovu 5, 121 16 Prague 2, Czech Republic

Systems with a very weak exchange coupling between magnetically ordered layers represent an interesting intermediate stage between the well-known isotropic bulk magnets and the recently intensively studied 2D magnets [1]. We perform a complex investigation of lattice and magnetic excitations induced by external perturbations in such quasi-2D system, trihalide VI_3, employing the synergy of DFT calculations, infrared, THz, and Raman spectroscopies [2]. The transition to the long-range ferromagnetic order is accompanied by the observed variations of phonon frequencies indicating strong magnetoelastic coupling. The acoustic magnon mode acquires here unusually high energy reaching to the THz range, but dramatically softens at temperatures where a second lattice distortion has been reported. First-principles calculations also show the strong connection of magnetic ordering and anisotropy to the lattice and its low temperature distortions [3]. These findings suggest the possibility of controlling magnetic anisotropy in this system by selective occupation of specific lattice modes. In this way magnon spectra would be strongly modified as well. We also show changes induced by strong magnetic fields in VI_3 and similar systems.
[1] M. Gibertini et al., Nat. Nanotech. 14, 408 (2019)
[2] D. Hovančík et al., J. Phys. Chem. Lett. 13, 11095 (2022)
[3] L. M. Sandratskii, K. Carva, Phys. Rev. B 103, 214451 (2021)

15 min. break

MA 21.5 Tue 16:15 HSZ 403

Characterisation of the Ising-tye 2D magnet $FePS_3$: A DFT+U study — Mohammad Amirabbasi and •Peter Kratzer — Faculty of Physics, University Duisburg-Essen, 47057 Duisburg, Germany

Among the 2D magnetic system that can be prepared via exfoliation, iron phosphorus trisulfide ($FePS_3$) excels due to its unusual Ising-type magnetic order which makes it interesting for applications in spintronic nano-devices. We carried out a computational study of the structural and magnetic properties of single-layer $FePS_3$ by using Density Functional Theory (DFT+U). Our findings show that the sublattice of the Fe^{2+} ions is not a perfect honeycomb; rather the nearest-neighbor Fe distances vary by 0.14 Å as a result of orbital ordering. These lattice distortions, albeit small, trigger different (ferromagnetic and antiferromagnetic) exchange couplings so that the ground state consists of ferromagnetically aligned zig-zag chains along the long Fe-Fe bonds which couple antiferromagnetically along the shorter Fe-Fe bonds of the distorted honeycomb. Within the DFT+U framework, we parameterize a spin Hamiltonian including Heisenberg, single-ion anisotropy, Dzyaloshinskii-Moriya and biquadratic interactions that allows us to calculate the critical temperature and the magnon spectrum. By comparing to prior results from neutron scattering, we conclude that it is the upper magnon branch in a doubled unit cell that has been observed in these experiments.

MA 21.6 Tue 16:30 HSZ 403

Interaction parameters in magnetic 2D systems from symmetric invariants — •Jonathan Kipp[1,2], Yuriy Mokrousov[2,3], and Fabian R. Lux[3] — [1]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [2]Institute for Advanced Simulation, Forschungszentrum Jülich Wilhelm-Johnen-Straße, 52428 Jülich — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The electronic properties of 2D materials hosting complex magnetic order can have crucial implications for information storage and processing applications. At the heart of the complexity in these materials is the interplay of external fields, fluctuations and electronic structure with the magnetic properties. In this work, we are aiming to uncover the direct implications that changes in the magnetic texture have on the electronic characteristics of the system. We develop an expansion in terms of the textures symmetric invariants and compare to data obtained from Heisenberg Hamiltonians, tight-binding (TB) calculations or possibly even density functional theory (DFT) calculations by employing a machine learning (ML) algorithm for the fitting task. Specifically, this enables us to identify the relevant interaction terms from the expansion to the total energy, since there is a diverse palette of ML fitting algorithms aiming at sparse models with the smallest possible number of coefficients, including regularized and sequential approaches.

MA 21.7 Tue 16:45 HSZ 403

Locally driven quantum phase transition cascades in a strongly correlated molecular monolayer — Soroush Arabi[1,2,3], Taner Esat[2,5], Aizhan Sabitova[2,5], Yuqi Wang[2,3], Hovan Lee[7], Cedric Weber[7], Klaus Kern[3,4], F. Stefan Tautz[1,2,5], Ruslan Temirov[2,6], and •Markus Ternes[1,2,5] — [1]Institute of Physics IIB, RWTH Aachen University, 52074 Aachen, Germany — [2]Peter-Grünberg-Institute (PGI 3), Research Center Jülich, 52425 Jülich, Germany — [3]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [4]Institut de Physique, École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [5]Jülich Aachen Research Alliance, 52425 Jülich, Germany — [6]Institute of Physics II, University of Cologne, 50937 Cologne, Germany — [7]King's College London, Theory and Simulation of Condensed Matter, London WC2R 2LS, UK

The molecular monolayer of 1,4,5,6-naphthalene tetracarboxylic acid dianhydride on Ag(111) creates a perfectly ordered lattice of π-conjugated organic molecules. Using a movable atomically sharp electrostatic gate we drive this lattice of strongly correlated electrons through a cascade of quantum phase transitions. Performing spectroscopic imaging with sub-Angstrom resolution, we show that as the gate field is increased, the molecular building blocks change from a Kondo-screened to a paramagnetic phase one by one, enabling us to reconstruct their complex interactions in detail. We anticipate that the supramolecular nature of the system will, in future, allow engineering quantum correlations in arbitrary patterned structures.

MA 21.8 Tue 17:00 HSZ 403

Electrically Tunable Curie Temperature in a 2D Ferromagnetic Semiconductor — •Tania Mukherjee[1,2] and Soumya Jyoti Ray[1] — [1]Department of Physics, Indian Institute of Technology Patna, Bihta 801106, India — [2]Institute of Optics and Atomic Physics, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany

Magnetic van der Waal's nanocrystals with intrinsic magnetic anisotropy provide an ideal platform for exploring magnetism in the low-dimensional limit. We investigate the electronic and magnetic properties of a novel 2D material $VClBr_2$ by using spin polarised density functional theory calculations. We observe complex electronic and magnetic phase transitions, tunable bandgap, and extremely large enhancement of the Curie temperature under the application of strain (η) and electric field (Ez). A Monte Carlo approach to the resolution of the Ising model reveals that the Curie temperature (T_c) can reach up to 340K under the application of an E_z = 2.5 V/nm, a colossal enhancement of $\sim$ 6700% of its base value. The coexistence of high-temperature spin-ordering along with large magnetic anisotropic energy (MAE), high magnetic moment, tunable band gap, and excellent stability make single layer $VClBr_2$ a promising material for applications in an electric field driven spin gating, room temperature spintronics, and 2D spin circuit design.

MA 22: Terahertz Spintronics

Time: Tuesday 15:00–16:15 Location: POT 6

MA 22.1 Tue 15:00 POT 6

Optimizing spin-based terahertz emission from magnetic heterostructures — •Francesco Foggetti, Francesco Cosco, and Peter M. Oppeneer — Uppsala University, Uppsala, Sweden

Terahertz radiation pulses can be generated efficiently through femtosecond laser excitation of a magnetic heterostructure, where an ultrafast laser-induced spin current results in an electromagnetic THz pulse due to the inverse spin Hall effect. It is however still poorly known how the THz emission amplitude and its bandwidth in the frequency regime can be optimized. Here, we perform a systematic analysis of the THz emission from various magnetic heterostructures. The dynamics of the spin current is described by the semiclassical, superdiffusive spin-transport model and, in order to identify the optimal setup for the THz emission, the properties of the wave profile are studied by changing the materials of the heterostructures, their thicknesses, and the laser pulses, allowing us to give optimization guidelines. The energy dependence of spin Hall effect of hot electrons is furthermore taken into account, leading to emission profiles comparable to experiment.

MA 22.2 Tue 15:15 POT 6

Terahertz probing of interfacial Curie temperatures in spintronic thin-film stacks — •Oliver Gueckstock[1], Reza Rouzegar[1], Vincent Baltz[2], Gerhard Jakob[3], Mathias Kläui[3], Tom S. Seifert[1], and Tobias Kampfrath[1] — [1]FU Berlin, Germany — [2]SPINTEC, France — [3]JGU Mainz, Germany

Transport of spin angular momentum and spin-charge-current interconversion are fundamental operations for future spin-electronic devices. Femtosecond laser pulses are well suited to trigger ultrafast spin transport from a ferromagnetic metal F into an adjacent paramagnetic layer P [1,2]. The inverse spin Hall effect converts the spin current into an in-plane charge current that gives rise to the emission of an electromagnetic pulse with frequencies extending into the terahertz (THz) range. As the ultrafast currents are confined to only ~1 nm around the F/P interface, the emitted THz pulse is expected to be a highly sensitive probe of interface properties. Here, we investigate the impact of the F/P interface morphology and sample temperature on the THz-emission signal. We find that the temperature-dependence of the THz emission signal depends critically on the roughness of the F/P interface. We conclude that the Curie temperature of F at the F/P interface is strongly reduced relative to the bulk by the higher degree of disorder at the F/P interface.

References [1] T. Seifert et al., Nature Photonics 10, 483 (2016). [2] R. Rouzegar et al., Physical Review B 106, 144427 (2022).

MA 22.3 Tue 15:30 POT 6

Switching and excitation of THz spin waves in Mn_2Au due to femtosecond spin-transfer torques — •Markus Weissenhofer[1,2], Francesco Foggetti[1], and Peter Oppeneer[1] — [1]Department of Physics and Astronomy, Uppsala University — [2]Department of Physics, Free University Berlin

In trilayer spin valves consisting of Fe|Cu|Fe, ultrafast laser pulses can generate hot-electron spin currents that exert spin-transfer torques, which excite THz spin waves [1]. Here, we replace the second Fe layer by antiferromagnetic Mn_2Au and demonstrate that spin waves with even higher frequencies can be excited. We compute the temporal evolution of the hot-electron spin currents by means of the superdiffusive transport model and simulate the response of the Mn_2Au layer to the resulting femtosecond spin-transfer torque pulse using atomistic spin dynamics simulations. Our results reveal that - due to the small thickness of the Mn_2Au layer and exchange enhancement - standing spin waves of up to several THz can be excited. Upon increasing the laser fluence, we even find that the excited spin-current pulses are sufficient to induce switching of Mn_2Au layer, faster than the experimentally demonstrated electrically induced switching of Mn_2Au [2].

[1] U. Ritzmann, P. Baláž, P. Maldonado, K. Carva, and P. M. Oppeneer, Phys. Rev. B 101, 174427 (2020).

[2] S. Y. Bodnar, L. Šmejkal, I. Turek, T. Jungwirth, O. Gomonay, J. Sinova, A. A. Sapozhnik, H.-J. Elmers, M. Kläui, and M. Jourdan, Nature Communications 9, 348 (2018).

MA 22.4 Tue 15:45 POT 6

Element-selective and THz study of spin dynamics in Fe/Ru/Ni tri-layer systems — •Christian Greb[1,2], Roman Adam[1], Daniel Bürgler[1], Sarah Heidtfeld[1,2], Markus

Büscher[1,3], and Claus M. Schneider[1,2] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich,52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [3]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

Ultrafast spin dynamics induced by femtosecond optical laser pulses in ferromagnetic thin films are of great interest due to their high potential for future information technology. Relevant materials are often multi-element compounds or multilayer stacks. We present an element-selective study of Ni/Ru/Fe/MgO(capping) multilayers in which Ni and Fe layers are coupled either ferromagnetically or antiferromagnetically, depending on the Ru thickness. The spin dynamics in the multilayers can be explained by super-diffusive spin transport [1,2]. In addition to element-selective T-MOKE measurements using a high harmonic generation source, we measured and analyzed THz transients [3] to gain further insight into the non-equilibrium interlayer spin transport. We show that spin currents can be triggered at lower laser fluences (<1uJ/cm2) than previously reported [1]. The THz amplitude as a function of the external magnetic field gives insights into the interlayer exchange coupling. [1] D. Rudolf et al., Nature Commun. 3, 1037 (2012). [2] M. Battiato et al., Phys. Rev. Lett. 105, 027203 (2010). [3] R. Adam et al., Appl. Phys. Lett. 114, 212405 (2019).

MA 22.5 Tue 16:00 POT 6

Impact of the magnetic layer crystal growth optimization on the THz emission from spintronic Fe/Pt emitters — •Laura Scheuer[1], Agne Ciuciulkaite[2], Anna L. Ravensburg[2], Merlin Pohlit[2], Tobias Warnatz[2], Garik Torosyan[3], René Beigang[1], Georg Schmidt[4], Evangelos Th. Papaioannou[4], and Vassilios Kapaklis[2] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663, Kaiserslautern, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Photonic Center Kaiserslautern, 67663, Kaiserslautern, Germany — [4]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 2, 06120 Halle, Germany

We investigate the THz emission characteristics of ferromagnetic/nonmagnetic metallic heterostructures, focusing on thin Fe/Pt bilayers. In particular, we report on the impact of optimized crystal growth of the epitaxial Fe layers on the THz emission amplitude and spectral bandwidth. We demonstrate a 5% enhancement of the emitted intensity related to structural quality of the Fe layer. Our work provides a pathway for optimal spintronic THz emitters devices based on epitaxial Fe. It also highlights how THz emission measurements can be utilized to characterize the changes in out-of-equilibrium spin current dynamics in metallic heterostructures, driven by subtle structural refinement.

MA 23: Poster Magnetism I

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

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

MA 23.1 Tue 17:00 P1

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

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

MA 23.2 Tue 17:00 P1

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

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

MA 23.3 Tue 17:00 P1

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

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

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

MA 23.4 Tue 17:00 P1

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

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

MA 23.5 Tue 17:00 P1

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

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

MA 23.6 Tue 17:00 P1

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

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

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

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

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

MA 23.7 Tue 17:00 P1

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

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

MA 23.8 Tue 17:00 P1

Design of an rf antenna for fast skyrmion lattice relaxation — •Ephraim Spindler[1], Philipp Schwenke[1], Abbass Hamadeh[1], Raphael Gruber[2], Vitaliy Vasyuchka[1], Mathias Kläui[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany

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

MA 23.9 Tue 17:00 P1

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

Dzyaloshinskii-Moriya interaction can lead to the formation of skyrmions in crystal lattices with a broken inversion symmetry, as it is the case at interfaces of artificial heterostructures. Néel-type skyrmions were proposed to form in bilayers of ferromagnetic $SrRuO_3$ and paramagnetic $SrIrO_3$ with strong spin-orbit coupling as indicated by the observation of a topological hall effect [1].
Heterostructures of $SrRuO_3$ and $SrIrO_3$ on $SrTiO_3$ substrates show a rather bad structural compatibility due to the large lattice mismatch of about 1.1 % between $SrIrO_3$ and the substrate. To address this, we reduced the lattice constant of the iridate by doping it with calcium. Superlattices composed of $[SrRuO_3]_5/[Ca_xSr_{1-x}IrO_3]_2$ with various

levels of doping were grown on STO (001) substrates by the means of metal-organic aerosol deposition. The structural properties of the samples were studied by x-ray diffraction, reciprocal space mapping and TEM imaging. Hall measurements were carried out to search for topological contributions as an indication for the formation of skyrmions and compared with the results of [1,2].

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

MA 23.10 Tue 17:00 P1

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

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

MA 23.11 Tue 17:00 P1

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

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

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

MA 23.12 Tue 17:00 P1

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

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

MA 23.13 Tue 17:00 P1

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

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

MA 23.14 Tue 17:00 P1

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

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

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

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

MA 23.15 Tue 17:00 P1

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

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

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

MA 23.16 Tue 17:00 P1

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

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

MA 23.17 Tue 17:00 P1

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

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

MA 23.18 Tue 17:00 P1

Magnetocaloric materials for the liquefaction of hydrogen — •Tino Gottschall[1], Eduard Bykov[1,2], Marc Strassheim[1,2], Timo Niehoff[1,2], Catalina Salazar-Mejia[1], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

Magnetic cooling is a refrigeration technique that is based on the so-called magnetocaloric effect, the change of temperature caused by a magnetic field. It can be utilized to construct environmentally friendly cooling devices, air conditioners, and heat pumps. Originally, magnetic cooling was used to achieve ultra-low temperatures by adiabatic demagnetization of magnetic salts. Recently, low temperatures have once again become the focus of attention as an area of application for magnetocaloric cooling namely for hydrogen liquefaction. In this work, we would like to discuss our current progress for the creation of a materials library for cryogenic applications. The basis for this is our characterization infrastructure for materials research at the Dresden High Magnetic Field Laboratory in static and pulsed fields. With this, we aim to understand these materials better to further optimize their magnetic cooling performance near the boiling temperature of hydrogen.

MA 23.19 Tue 17:00 P1

Direct measurements of the adiabatic temperature change in heavy rare-earth RCo_2 compounds in high magnetic fields — •E. Bykov[1,2], T. Gottschall[1], K. Skokov[3], A. Karpenkov[3], W. Liu[3], F. Scheibel[3], O. Gutfleisch[3], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Technische Universität Darmstadt, Darmstadt, Germany

Rare-earth elements and their intermetallic compounds are interesting candidate materials for magnetic cooling at and below room temperature. Although the group of heavy rare-earth Laves phases RM_2 (R is a rare earth, M a transition metal) is one of the most intensively investigated classes of magnetocaloric materials, data on directly determined adiabatic temperature changes are scarce. Continuing our work with ferromagnetic RNi_2 and RAl_2 compounds, we are now focussed on ferrimagnetic RCo_2. Some of them show complex magnetic behavior, such as metamagnetism at T_C, or an additional spin-reorientation transition and reduction of the Co magnetic moment below this temperature. In this work, we present a comprehensive analysis of the magnetocaloric effect in polycrystalline RCo_2 with R = Er, Ho, Dy, and Tb in high magnetic fields up to 20 T.

MA 23.20 Tue 17:00 P1

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

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

MA 23.21 Tue 17:00 P1

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

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

MA 23.22 Tue 17:00 P1

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

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

MA 23.23 Tue 17:00 P1

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

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MA 23.24 Tue 17:00 P1

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

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

MA 23.25 Tue 17:00 P1

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

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

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

MA 23.26 Tue 17:00 P1

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

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

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

MA 23.27 Tue 17:00 P1

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

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

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

MA 23.28 Tue 17:00 P1

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

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

MA 23.29 Tue 17:00 P1

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

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

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

MA 23.30 Tue 17:00 P1

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

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

MA 23.31 Tue 17:00 P1

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

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

MA 23.32 Tue 17:00 P1

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

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

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

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

MA 23.33 Tue 17:00 P1

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

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

MA 23.34 Tue 17:00 P1

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

gasta, Chile — [3]Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, 09126 Chemnitz, Germany

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

MA 23.35 Tue 17:00 P1

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

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

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

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

MA 23.36 Tue 17:00 P1

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

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

MA 23.37 Tue 17:00 P1

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

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

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

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

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

MA 23.38 Tue 17:00 P1

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

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

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

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

MA 23.39 Tue 17:00 P1

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

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

MA 23.40 Tue 17:00 P1

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

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

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

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

MA 23.41 Tue 17:00 P1

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

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

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

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

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

MA 23.42 Tue 17:00 P1

Analysing the Domain Structure of a Thin Film and a GMR Stack with Magnetic Transmission Electron Microscopy — •Judith Bünte, Björn Büker, Daniela Ramermann, Inga Ennen, and Andreas Hütten — Universität Bielefeld, Dünne Schichten und Physik der Nanostrukturen, Universitätsstr. 25, 33615 Bielefeld, Germany

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

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

MA 23.43 Tue 17:00 P1

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

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

MA 23.44 Tue 17:00 P1

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

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

MA 23.45 Tue 17:00 P1

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

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

MA 23.46 Tue 17:00 P1

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

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

MA 23.47 Tue 17:00 P1

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

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

MA 23.48 Tue 17:00 P1

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

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

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

MA 23.49 Tue 17:00 P1

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

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

MA 23.50 Tue 17:00 P1

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

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

MA 23.51 Tue 17:00 P1

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

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

MA 23.52 Tue 17:00 P1

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

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

MA 23.53 Tue 17:00 P1

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

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

MA 23.54 Tue 17:00 P1

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

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

[1] Spintronic emitters for super-resolution in THz-spectral imaging Appl. Phys. Lett. 120, 032406 (2022); https://doi.org/10.1063/5.0076880

MA 23.55 Tue 17:00 P1

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

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

MA 23.56 Tue 17:00 P1

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

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

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

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

MA 23.57 Tue 17:00 P1

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

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

MA 23.58 Tue 17:00 P1

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

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

MA 23.59 Tue 17:00 P1

Dependence of resistance area product and tunnel magnetoresistance on MgO crystalline quality in CoFeB/ MgO/ CoFeB Magnetic Tunnel Junctions — •Tobias Peters und Günter

Reiss — Center for Spinelectronic Materials and Devices, University of Bielefeld, Germany

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

MA 23.60 Tue 17:00 P1

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

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

MA 23.61 Tue 17:00 P1

Coupling Strength Controlling Vortex Trajectories' Oscillations in Coupled Vortices Spintronic Oscillator — •Abbass Hamadeh[1], Abbas Koujok[1], Salvatore Perna[2], Steffen Wittrock[3], Vitaliy Lomakin[4], Gregoire de Loubens[5], Olivier Klein[6], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]University of Naples Federico II, Naples, Italy — [3]Max-Born-Institute for Nonlinear Optics & Short Pulse Spectroscopy, Berlin, Germany — [4]Center for Magnetic Recording Research, Uni. of California San Diego, La Jolla, California 92093-0401, USA — [5]SPEC, CEA, CNRS, Université Paris-Saclay, 91191 Gif-sur-Yvette, France — [6]Univ. Grenoble Alpes, CEA, CNRS, Grenoble INP, INAC-Spintec, 38054 Grenoble, France

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

MA 23.62 Tue 17:00 P1

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

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

MA 23.63 Tue 17:00 P1

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

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

MA 23.64 Tue 17:00 P1

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

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

MA 23.65 Tue 17:00 P1

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

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

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

MA 23.66 Tue 17:00 P1

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

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

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

MA 23.67 Tue 17:00 P1

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

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

MA 23.68 Tue 17:00 P1

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

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

MA 23.69 Tue 17:00 P1

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

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

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

MA 23.70 Tue 17:00 P1

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

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

MA 23.71 Tue 17:00 P1

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

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

MA 23.72 Tue 17:00 P1

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

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

We acknowledge funding by DFG via project No. 492421737.

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

MA 23.73 Tue 17:00 P1

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

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

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

MA 23.74 Tue 17:00 P1

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

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

MA 23.75 Tue 17:00 P1

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

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

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

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

MA 23.76 Tue 17:00 P1

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

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

MA 23.77 Tue 17:00 P1

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

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

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

MA 23.78 Tue 17:00 P1

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

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

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

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

MA 23.79 Tue 17:00 P1

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

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

MA 23.80 Tue 17:00 P1

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

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

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

MA 24: Molecular Magnetism II

Time: Wednesday 9:30–11:00 Location: HSZ 02

MA 24.1 Wed 9:30 HSZ 02

Studies of decoherence in strongly anisotropic spin triangles with toroidal or general non-collinear easy axes — Kilian Irländer and •Jürgen Schnack — Universität Bielefeld, Bielefeld, Deutschand

Magnetic molecules are investigated with respect to their usability as units in future quantum devices. In view of quantum computing, a necessary prerequisite is a long coherence time of superpositions of low-lying levels. In this article, we investigate by means of numerical simulations whether a toroidal structure of single-ion easy anisotropy axes is advantageous as often conjectured. Our results demonstrate that there is no general advantage of toroidal magnetic molecules, but that arrangements of tilted anisotropy axes perform best in many cases.

MA 24.2 Wed 9:45 HSZ 02

Electrically driven singlet-triplet transition in triangulene spin-1 chains — Gabriel Martínez-Carracedo[1,2], •László Oroszlany[3,4], Amador García-Fuente[1,2], László Szunyogh[5,6], and Jaime Ferrer[1,2] — [1]Universidad de Oviedo, Oviedo, Spain — [2]CINN, Universidad de Oviedo-CSIC, El Entrego, Spain — [3]Eotvos Lorand University, Budapest, Hungary — [4]MTA-BME Lendulet Topology and Correlation Research Group, Budapest University of Technology and Economics, Budapest, Hungary — [5]Budapest University of Technology and Economics, Budapest, Hungary — [6]ELKH-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budapest, Hungary

Recently, graphene triangulene chains have been synthesized and their magnetic response has been analyzed by STM methods by Mishra and coworkers (Nature 598, 287 (2021)). Motivated by this study, we determine the exchange bilinear and biquadratic constants of the triangulene chains by calculating two-spin rotations in the spirit of the magnetic force theorem. We then analyze open-ended, odd-numbered chains, whose edge states pair up forming a triplet ground state. We propose three experimental approaches that enable us to trigger and control a singlet-triplet spin transition. Two of these methods are based on applying a mechanical distortion to the chain. We finally show that the transition can be controlled efficiently by the application of an electric field.

MA 24.3 Wed 10:00 HSZ 02

Linear magnets: a structure-property-relation for finding unquenched orbital moments — •Anton Jesche — EP VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86135 Augsburg, Germany

The presence of orbital magnetic moments in rare-earth-elements is one of the major differences to transition metal compounds and is at the heart of magnetic anisotropy, stability, and functionality. A large crystal electric field effect acting on an unquenched orbital moment can lead to extremely large anisotropy and coercivity as experimentally verified for iron-doped lithium nitride [1]. In the dilute limit, those iron atoms can be considered as single-atom magnets and are ideal candidates to study the quantum dynamics of anisotropic spins [2,3]. This, together with the strong field dependence of the spin reversal, allows the creation of stable but switchable states that could act as a 'quantum bit' at elevated temperatures of 10 K. A recent Mössbauer study revealed dominant magnetic quantum tunneling at even higher temperatures [4]. The presence of orbital moments in iron-doped lithium nitride is not a coincidence and not a solitary case: based on the proposed structural motif of the 'linear chain', we have identified several other 'linear magnets' with similar physical properties: iron-doped Li4SrN2, LiSr2(CoN2), and (Sr6N)[FeN2][CN2]2. Implications and limitations of linear coordination are discussed in relation to the electronic structure. [1] M. Fix et al. PRB 97, 064419 (2018) [2] M. Fix et al. PRL 120, 147202 (2018) [3] M. Huzan et al. Chem. Sci. 11, 11801 (2020) [4] S. A. Bräuninger et al. PRB 102, 054426 (2020)

MA 24.4 Wed 10:15 HSZ 02

Modelling of saw-tooth chain molecules composed of 3d and 4f ions — •Dennis Westerbeck and Jürgen Schnack — Universität Bielefeld, D-33501 Bielefeld, Deutschland

Metal- and lanthanide-ion containing systems are of great interest for the investigation of the magnetic properties of molecular systems. Especially the gadolinium containing systems are promising in view of magnetocaloric applications. In addition, saw-tooth like systems are considered as favorable for low-temperature cooling due to their massively degenerate ground-state. Although Fe^{III} and Gd^{III} are mostly considered as isotropic in multi-ion systems, we show that zero-field splittings are inevitable for the proper description of some of these molecules. Furthermore, these anisotropic saw-tooth systems show a significant isothermal entropy change, which is surprisingly well described by our simulations.

MA 24.5 Wed 10:30 HSZ 02

High-field/high-frequency EPR studies on heterometallic 3*d*-4*f*-complexes — •Jan Arneth[1], Changyun Koo[1], Xiangfeng Li[2], Annie K. Powell[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Institute of Inorganic Chemistry, Karlsruhe Institute of Technology, Germany

On the road to the construction of novel efficient single molecular magnets and molecular magnetic refrigerants experimental investigation of the exchange coupling mechanism between $4f$ and $3d$ moments is an important, yet still challenging, task. The difficulty in understanding the rich physics underlying this coupling arises from the strong participation of orbital angular momentum leading to large anisotropy and a complex energy spectrum in $4f$ metal compounds. Here, we present high-field/high-frequency electron paramagnetic resonance (HF-EPR) studies on heterometallic $3d$-$4f$ complexes with so-called butterfly motif Fe_2Ln_2 (Ln = Y, Gd, Dy), V_2Ln_2 (Ln = Er, Ho) and in the saw-tooth coordination V_4Ln_4 (Ln = La, Gd), which allow us to directly determine not only the exchange coupling constants but also other spin-hamiltonian parameters, such as g-values and anisotropy. Our spectroscopic measurements are further complemented by high-field magnetisation studies.

MA 24.6 Wed 10:45 HSZ 02

AOM-guided Linked Fits for Analysing Inelastic Neutron Scattering and Magnetic Data 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 two decades ago of slow relaxation and quantum tunnelling of the magnetization in the single molecule magnets (SMMs) has inspired a flurry of research into their magnetic properties. This class of molecules has been extended to heterometallic clusters containing ions of transition metals and rare earths. The $4f$ ions are of interest because of their large angular momentum and magnetic anisotropies, but also present challenges in the analysis of inelastic neutron scattering (INS) and magnetic data. As presented in the previous meeting, excellent INS data were recorded on the time-of-flight disk-chopper spectrometers IN5 and IN6 at ILL on the Mn_2Ln_2-squares with Ln = Y, Tb, Ho, Dy, and the M_2Ln_2-butterflies with M = Fe, Al and Ln = Dy, Er. In this talk, the analysis of the complete set of magnetic data using an AOM-guided linked fit is presented. The resulting ligand field and coupling parameters give crucial hints for the analysis of the rich INS spectra.

MA 25: Focus Session: Startups in Magnetism

This session offers academic researchers an insight into a possible third career path, besides staying in science or going to industry. Building your own company can be very rewarding and fun, big decisions to make decide over success or failure. 5 young entrepreneurs describe their business cases developed out of our magnetism community and will explain challenges, pitfalls, university support and constraints, IP, legal and business issues. After the talks there is a Panel Discussion with all speakers and Q and A with the audience.

Organizers: Manfred Fiebig (ETH Zürich) and Oliver Gutfleisch (TU Darmstadt).

Time: Wednesday 9:30–12:30 Location: HSZ 04

Invited Talk MA 25.1 Wed 9:30 HSZ 04

MAGNOTHERM – One way to start a deep tech spin-off from research — •Max Fries — MagnoTherm Solutions GmbH, Pfungstädter Straße 102, 64297 Darmstadt

Founded as a spin-off from Prof. Oliver Gutfleisch's Functional Materials group at Technische Universität Darmstadt in 2019, MAGNOTHERM holds world-leading expertise in permanent magnets and magnetic cooling.

Our technology, based on solid state materials and water, is capable of revolutionizing the way we provide temperatures: By updating the standard gas compression cycle by our magnetic refrigeration cycle, we can build the next-generation cooling or heating solutions.

What does it mean for scientists to become entrepreneurs? What does it need to transform innovative research into market-ready, valuable products? From initial idea, raising first (venture) capital and sales over to recruiting talents and building a diverse team, I will take you along my professional journey so far. Doing so, I will highlight my personal key learnings along the way, while still providing time for a vivid discussion.

My aim is to motivate and inspire potential founders as well as up and coming Startup-entrepreneurs with a scientific background to implement their ideas by themselves, developing a beneficial impact on the world of today and the future.

Invited Talk MA 25.2 Wed 10:00 HSZ 04

Spin-Ion Technologies : taking the research from a lab to a start-up company — •Dafiné Ravelosona — Spin-Ion Technologies, 10 Bd Thomas Gobert, 91120 Palaiseau, FRANCE

At Spin-Ion technologies, we have developed a new manufacturing process based on He ion irradiation to tailor the structural properties of ultra-thin magnetic films and spintronic devices at atomic level and improve their performance. The key feature of the technology is the post-growth control at the atomic scale of structural properties, which enables a precise control of magnetic properties. When realized through a mask this technology enables lateral modulation of magnetic properties without any physical etching. In this talk, I will describe the development of our idea from a research lab to a start-up company and how we envision our development toward the commercialization of our solution.

Invited Talk MA 25.3 Wed 10:30 HSZ 04

MagREEsource : the green Rare Earth Magnet company — •Sophie Rivoirard[1,2] and Erick Petit[2] — [1]CNRS-UGA/Institut Neel, Grenoble, France — [2]MagREEsource SAS, Grenoble, France

Nd-Fe-B is the most widely used hard magnetic material in applications including the electronic and automotive sectors, electromobility and wind powder (e.g. motors, turbines, magnetic valves, sensors). Current standard Nd-Fe-B magnets contain up to 30% of rare earth elements, such as Neodymium or Dysprosium, which are on the EU list of critical elements and which are, for more than 95%, mined in the People*s Republic of China. This sourcing raises both environmental and geopolitical issues while the present demand for rare earth magnets is increasing by a rate of nearly 9%/year due to an increasing production of green technologies items (electric vehicles, wind turbines*). Therefore, one incentive in the European Union is to develop recycling processes for Nd-Fe-B magnets. MagREEsource is a spin off company from CNRS founded in 2020, which benefits from more than 25 years of expertise within CNRS laboratories in Grenoble. MagREEsource has licensed the know-how and Intellectual Property developped in Neel Institute at CNRS Grenoble on the recycling of Rare Earth based magnets. MagREEsource is currently working on an industrial plant in the Rhone-Alpes region to start high scale production. As a player in the Circular Economy, MagREEsource's objective is therefore to promote magnets at the end of their life, by producing new magnets for European manufacturers of motors promoting a loop as short as possible between supply and customer.

Invited Talk MA 25.4 Wed 11:00 HSZ 04

THATec Innovation – we automate your lab — •Thomas Sebastian — THATec Innovation GmbH, Ludwigshafen, Deutschland

The idea behind THATec Innovation was born in the lab with the major goal to develop hardware and software solutions to overcome the challenges many scientists face in their daily work. Based on our longstanding experience as experimentalists, our services encompass the following areas: the automation of laboratory devices, optical scanning microscopy, and Brillouin light scattering.

THATec Innovation GmbH was founded in 2016 as a spin-off of the Helmholtz Center Dresden-Rossendorf and supported by the Helmholtz association in the framework of the Helmholtz Enterprise program. Since then, THATec Innovation offers the software framework thaTEC:OS for laboratory automation as well as software and hardware for Brillouin light scattering spectroscopy and microscopy.

In this talk, I am going present the experiences I gathered from the foundation of THATec Innovation as well as from my day-to-day business.

Invited Talk MA 25.5 Wed 11:30 HSZ 04

Kiutra: Magnetic refrigeration for science and technology — •Alexander Regnat[1], Jan Spallek[1], Tomek Schulz[1], and Christian Pfleiderer[1,2] — [1]kiutra GmbH, D-81369 Munich, Germany — [2]Physik-Department, Technische Universität München, D-85748 Garching, Germany

Kiutra was founded in 2018 as a spin-off of the Technical University of Munich. With an interdisciplinary team of more than 30 employees, we innovate cryogenics to provide the best, most scalable and sustainable cooling solutions for basic research, material science and applied quantum technologies. Our products and services are successfully used by academic and industrial customers in Germany, Europe and the USA. Here we report on the scientific roots of our company, as well as the main challenges and successes we experienced developing our business. In addition, we highlight the various financing tools that have helped kiutra grow as a deep-tech hardware manufacturer.

30 min. Panel discussion with all speakers/industry representatives; then Q and A with the audience

MA 26: Non-Skyrmionic Magnetic Textures II

Time: Wednesday 9:30–11:30 Location: HSZ 401

Invited Talk MA 26.1 Wed 9:30 HSZ 401

The self-induced spin glass: the perplexing magnetism of elemental neodymium — •Alexander Khajetoorians — Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands

Spin glasses are a class of disordered magnetic materials characterized by a flat multi-well energy landscape that exhibits aging dynamics. Spin glass behavior is often described by two key ingredients: (a) competing spin interactions, and (b) external disorder. It was recently proposed that a special type of spin glass can be realized, solely by competing interactions (1). In 2020 (2), we discovered that the controversial and perplexing magnetic state of elemental Nd(0001) is a self-induced spin glass. Using spin-polarized scanning tunneling microscopy/spectroscopy (SP-STM/STS), we found that the zero-field state shows a multiplicity of favorable short-range ordered Q-states, but in the absence of long-range order. The magnetic state shows aging dynamics, and it stems from frustrated indirect exchange. More recently (3), we showed that with increasing temperature, frustration is broken leading to a long-range ordered multi-Q state. In this talk, I will review the concept of the self-induced spin glass in Nd. Moreover, I will discuss new results concerning the aging dynamics and magnetic phase diagram of the material, as well as perspectives to use such multi-well systems for new memory and computing applications. [1] A. Principi, M.I. Katsnelson, PRL, 117, 137201 (2016); [2] U. Kamber et al, Science, 368, 6494 (2020); [3] B. Verlhac, L. Niggli, et al, Nature Physics, 18, 905 (2022)

MA 26.2 Wed 10:00 HSZ 401

Low-temperature properties of single-crystal ErB_2 — •Christoph Resch, Georg Benka, Daria Nuzhina, Anh Tong, Andreas Bauer, and Christian Pfleiderer — Physik Department E51, Technische Universität München, 85748 Garching, Germany

We present a comprehensive study of single crystals of the hexagonal rare-earth diboride ErB_2 prepared by means of the optical floating-zone approach. Measurements of the specific heat, the ac susceptibility, the magnetisation, and the electrical transport at low temperatures and fields up to 18 T consistently establish magnetic order of the Er^{3+} moments below a second-order phase transition at $T_c = 14$ K with competing ferromagnetic and antiferromagnetic interactions. The magnetocrystalline anisotropies exhibit strong easy-plane characteristics with $\langle 001 \rangle$ being the magnetic hard axis.

MA 26.3 Wed 10:15 HSZ 401

Helitronics for unconventional computing — •Nicolai Timon Bechler[1] and Jan Masell[1,2] — [1]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]RIKEN CEMS, Wako, Japan

Non-trivial magnetic structures have been proposed to be a promising route to unconventional computing. The interplay between magnetic stiffness and Dzyaloshinskii-Moriya interaction can stabilize a helical order of the magnetisation which is often discarded as trivial. However, recent studies have shown that the orientation of these helical magnetisation structures can be manipulated by strong enough magnetic fields [1] and spin currents [2] which revealed their unexpectedly complex dynamics. Using micromagnetic simulations, we investigate novel magnetic memory devices such as MRAM-cells and memristors which use the orientation of the helical phase as an order parameter, dubbed helitronics. We propose a way to read-out said devices using the anisotropic magneto resistance and point out their use for unconventional computing purposes.

[1] A. Bauer, A. Chacon, M. Wagner, M. Halder, R. Georgii, A. Rosch, C. Pfleiderer, and M. Garst, Phys. Rev. B 95, 024429 (2017). [2] J. Masell, X. Z. Yu, N. Kanazawa, Y. Tokura, and N. Nagaosa,

Phys. Rev. B 102, 180402(R) (2020).

15 min. break

MA 26.4 Wed 10:45 HSZ 401

Investigating a stable Bloch point in a magnetic disk comprising layers with two different chiralities — •Thomas Brian Winkler[1], Marijan Beg[2], Martin Lang[3,4], Mathias Kläui[1], and Hans Fangohr[3,4] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Department of Earth Science and Engineering, Imperial College London, United Kingdom — [3]Faculty of Engineering and Physical Sciences, University of Southampton, United Kingdom — [4]Max Planck Institute for the Structure and Dynamics of Matter Hamburg, Germany

Bloch points (BPs) are highly confined spin structures, that often occur in transient processes [1]. However, they can also be stabilized in specific systems. Beg et al. showed the existence of a stable Bloch point by stacking two cylindrical nanodisks of FeGe on top of each other, with opposite sign of the DMI vector [2]. In both layers a magnetic vortex is formed, with the same circularity, but opposite polarity, leading to a Bloch point at the interface. In this study we investigate the energetics of the system within the micromagnetic (MM) framework and validate results with atomistic simulations. Further, an in-plane field is applied to shift the BP out of the center of the disk. The dynamics of the system are analysed after the field switch-off. The BP does not show any precessional motion, which is different to a classical magnetic vortex [3]. We also find, that qualitatively, the MM framework produces the same results as atomistic simulation.

[1] T. B. Winkler et al., PRApplied 16, 044014 (2021). [2] M. Beg et al., Sci Rep 9, 7959 (2019). [3] K. Yu. et al., JAP 91, 8037 (2002).

MA 26.5 Wed 11:00 HSZ 401

Stability of Hopfions in Bulk Magnets with Competing Exchange Interactions — •Moritz Sallermann[1,2,3], Hannes Jónsson[3], and Stefan Blügel[1] — [1]PGI-1 and IAS-1, Forschungszentrum Jülich and JARA, Jülich, Germany — [2]Department of Physics, RWTH Aachen, Aachen, Germany — [3]Science Institute and Faculty of Physical Sciences, University of Iceland, Reykjavík, Iceland

Magnetic hopfions are three-dimensional topological solitons, characterised by the Hopf number. Based on a micromagnetic model, the existence of free moving hopfions has been predicted in certain magnets with competing exchange interactions [1]. However, physical realisations of free moving hopfions in bulk magnets have so far been elusive. Here, we consider an effective spin lattice Heisenberg model with competing exchange interactions and computationally study the stability of small toroidal hopfions with unity Hopf number by finding first-order saddle points representing the transition state for the decay of hopfions to the ferromagnetic ground state, via the formation of two coupled Bloch points. We show that the energy barriers can reach substantial heights and are largely determined by the size of the hopfions. The saddle point methods are discussed.

We acknowledge funding by DFG through SPP 2137 and SFB 1238, through the Helmholtz-RSF Joint Research Group "TOPOMANN", the ERC under the EU Horizon 2020 research and innovation programme (no. 856538) and the Icelandic Research Fund (no. 185405-053).

[1] F. N. Rybakov *et al.*, Apl. Mater. **10**, 111113 (2022)

MA 26.6 Wed 11:15 HSZ 401

Blowing magnetic smoke rings (hopfions) — •Philipp Gessler[1] and Jan Masell[1,2] — [1]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]RIKEN CEMS, Wako, Japan

Hopfions are three-dimensional topological defects in magnetization, consisting of a closed skyrmion-string loop. Embedded in the field polarized phase, they are reminiscent of smoke rings in the air. In contrast to their two-dimensional counterparts, i.e. skyrmions, hopfions appear anything but ubiquitously in experiments. One reason is the lack of proposals for efficient ways to create these complex magnetic textures. Recently, ideas emerged for the creation of skyrmion-antiskyrmion pairs in two dimensions [1]. We generalize this idea to three dimensions. Using micromagnetic simulations, we show that spin-polarized currents can create hopfions at defects, similar to blowing smoke rings.

[1] K. Everschor-Sitte et al., New J. Phys. 19, 092001 (2017)

MA 27: Electron Theory of Magnetism and Correlations

Time: Wednesday 9:30–11:30 Location: HSZ 403

MA 27.1 Wed 9:30 HSZ 403

Electronic structure of the non-centrosymmetric antiferromagnetic $AgCrSe_2$ — •Seo-Jin Kim[1], Haijing Zhang[1], Marcus Schmidt[1], Michael Baenitz[1], Gesa Siemann[2], Chiara Bigi[2], Phil D. C. King[2], Vincent Polewczyk[3], Giovanni Vinai[3], and Helge Rosner[1] — [1]MPI CPfS, D-01187 Dresden, Germany — [2]IOM-CNR, Laboratorio TASC, Area Science Park, S.S. 14 km 163.5, Trieste I-34149, Italy — [3]School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, United Kingdom

We present the theoretical studies of the electronic structure and the anomalous Hall effect in $AgCrSe_2$ based on density functional theory together with experimental results. $AgCrSe_2$ is a layered triangular lattice system that lacks inversion symmetry. It exhibits a cycloidal coupling in the $CrSe_2$ layer with a small angle and an antiferromagnetic coupling between adjacent layers with a small canting along c-axis. The comparison of the Cr partial DOS determined from the photoemission measurements and the magnetic LDA+U calculations with a value of U = 0.75 eV shows a good agreement. This reveals that this compound is rather weakly correlated due to a strong hybridization with the ligands. The Se 4p states are dominating near the Fermi energy, resulting in a sizable band split of the order of 300 meV induced by the SOC. This system shows an unconventional anomalous Hall effect. The anomalous Hall conductivity is calculated based on the Berry curvature using an effective model constructed by the Wannierisation. The calculated σ_{xy} shows a good agreement to the experiments.

MA 27.2 Wed 9:45 HSZ 403

Geometrical dynamics of magnetic moments coupled to a correlated antiferromagnet — •David Alan Krüger, Nicolas Lenzing, and Michael Potthoff — Department of Physics, University of Hamburg, Hamburg, Germany

The geometrical spin torque represents an indirect interaction of magnetic moments, which are weakly exchange coupled to a system of itinerant electrons. It originates from a finite spin-Berry curvature, it modifies and adds to the conventional indirect RKKY exchange, and it leads to an anomalous, non-Hamiltonian dynamics of the magnetic moments. We demonstrate that there is an unprecedentedly strong geometrical spin torque in case of an electron system, where correlations cause antiferromagnetic long-range order. The key observation is that the anomalous torque is strongly boosted by low-energy magnon modes emerging in the two-electron spin-excitation spectrum as a necessary consequence of spontaneous spin-rotation symmetry breaking. As long as single- electron excitations are gapped out, the effect is largely universal, i.e., essentially independent of the details of the electronic structure, but decisively dependent on the lattice dimension. Analogous to the reasoning that leads to the Mermin-Wagner theorem, there is a lower critical dimension at and below which the spin-Berry curvature diverges. Our proposal is supported by numerical results obtained by the random-phase approximation and by Holstein-Primakov spin-wave theory for the Hubbard model in the weak- and in the strong-coupling limit, respectively.

MA 27.3 Wed 10:00 HSZ 403

Exploring electron correlation effects in the electronic structure and spin transport properties of transition metal multilayers — •Andrea Droghetti[1], Miloš Radonjić[2], Declan Nell[1], Liviu Chioncel[3], and Ivan Rungger[4] — [1]Trinity College Dublin (Ireland) — [2]University of Belgrade (Serbia) — [3]University of Augsburg (Germany) — [4]National Physical Laboratory (UK)

Magnetic thin film heterostructures, which are the material platforms for spintronic devices, are quite correlated systems. However, to date, most theoretical studies dedicated to their electronic and spin transport properties, rely on effective single-particle pictures. To go beyond these limitations, we present a computational approach, which

combines Density Functional and Dynamical Mean Field Theory, for layered systems, using a multi-orbital perturbative solver for the many-body problem [1]. Calculations accurately describe the spin splitting of 3d states and the appearance of satellite features at transition metal surfaces and interfaces, where electron correlations can get drastically enhanced [2]. Furthermore, when combined with quantum transport schemes [3], our method allows for the simulation of spintronic devices thus addressing how electron correlations affect the giant and tunnel magnetoresistance [4].

[1] A. Droghetti, M.M. Radonjić, A. Halder, I. Rungger, and L. Chioncel, Phys. Rev. B 105, 115129 (2022). [2] D.M. Janas, A. Droghetti, et al., Adv. Mater. 2205698 (2022). [3] A. Droghetti, I Rungger, Phys. Rev. B 95, 085131 (2017). [4] A. Droghetti, M.M. Radonjić, L. Chioncel, I. Rungger, Phys. Rev. B 106, 075156 (2022).

MA 27.4 Wed 10:15 HSZ 403

The role of non-local Coulomb interaction on spin models in the Hubbard limit — •Wejdan Beida, Markus Hoffmann, Juba Bouaziz, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA,52425 Jülich Germany

We extend the derivation of model spin Hamiltonians by including the non-local Coulomb interaction in the multi-band Hubbard model. We use Löwdin partitioning as the downfolding method of the dynamical electronic degrees of freedom described in the extended Hubbard model at half filling into low energy spin corner. The ground state of spin systems has been perturbatively corrected up to fourth order in the hopping parameter of the Hubbard model. The role which the non-local Coulomb interaction plays is strengthening the magnetism of the ground state. More importantly, it increases the importance of higher-order spin interactions beyond Heisenberg; Biquadratic, Four-spin, and Three-spin interactions. Generally speaking, this is confirmed by spin lattices with a site total spin in the range 1/2 * S * 3/2. For S = 1/2, we characteristically investigate the effect of next nearest neighbour hopping and inter-site Coulomb interaction on spin models for square and hexagonal lattice geometries.

15 min. break

MA 27.5 Wed 10:45 HSZ 403

Influence of the temperature on the relation between the magnetic hyperfine field and the magnetic moment — •Ondrej Sipr[1,2] 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 magnetic hyperfine field B_{hf} is often used to probe magnetism in alloys, compounds and doped systems in an element-specific way. Accompanying this is the question about the relationship between B_{hf} and the magnetic moment. It was shown before both experimentally and theoretically that the ratio between B_{hf} and the magnetic moment depends on the alloy system and the composition. Here, we apply ab initio calculations to investigate how B_{hf} and its relation to the magnetic moment depend on the temperature.

We find that the contribution of the core electrons to B_{hf} is indeed proportional to the magnetic moment over the whole temperature range, from zero up to the Curie temperature. However, the temperature-dependence of the contribution of the valence electrons is more complicated and as a result of this, the ratio between the total B_{hf} and the magnetic moment significantly varies with the temperature. Based on our theoretical results, we show that probing element-specific magnetism by means of measuring the magnetic hyperfine field and by measuring the x-ray magnetic circular dichroism will lead in general to different pictures.

MA 27.6 Wed 11:00 HSZ 403

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

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

MA 27.7 Wed 11:15 HSZ 403

Data-driven estimation of spin models in undoped cuprates — •Denys Y. Kononenko[1], Ulrich K. Rössler[1], Jeroen van den Brink[1,2], and Oleg Janson[1] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, Germany — [2]Institute for Theoretical Physics, TU Dresden, Dresden, Germany

Undoped cuprates host a wide variety of low-dimensional and frustrated spin models. The typically leading antiferromagnetic contribution to a magnetic exchange can be accurately estimated if the respective transfer integral is known. To date, the computational estimation of the transfer integral involves a well-established but cumbersome computational procedure. We demonstrate how the Gaussian Process Regression (GPR) model, trained on the results of the density functional theory calculations, can be employed to predict the transfer integrals using crystal structure as the only input. The GPR model receives descriptors of the local crystal environment of two copper sites as an input. The descriptors are based on the truncated expansion of the site position functions on the basis of the three-dimensional Zernike functions [1]. In this way, information on the spatial configuration and the chemical composition of the local crystal environment is incorporated into the descriptor. The approach facilitates rapid screening of spin models with desirable features among a broad range of known and unknown cuprates.

[1] M. Novotni and R. Klein, Computer Aided Design 36, 1047 (2004)

MA 28: Bulk Materials: Soft and Hard Permanent Magnets

Time: Wednesday 9:30–10:45 Location: POT 6

MA 28.1 Wed 9:30 POT 6

Local stiffness tailoring of magneto-active composites produced by laser powder bed fusion — •Kilian Schäfer[1], Matthias Lutzi[1], Muhammad Bilal Khan[1], Sebastian Bruns[2], Claas Hartmann[3], and Oliver Gutfleisch[1] — [1]Functional Materials, Institute of Materials Science, TU Darmstadt, — [2]Physical Metallurgy, Institute of Materials Science, TU Darmstadt, — [3]Measurement and Sensor Technology Group, TU Darmstadt,

Magnetic actuation of mechanically soft actuators allows fast response, wireless operation and safe interaction with the human body. With additive manufacturing, the production of magneto-active composites in complex and bioinspired shapes is possible. To mimic the properties of biological systems, the fabrication of composites with locally different mechanical properties is needed. Here, we present a method to locally tailor the stiffness of a magneto-active compound, consisting of hard magnetic Nd2Fe14B particles in a thermoplastic polyurethane (TPU) matrix with laser powder bed fusion. By utilizing different laser parameters at different locations during the process, the mechanical properties of the composite are modified locally. The range in which the mechanical properties can be tailored is investigated with compression and tensile tests of the composite produced with different laser parameters. The stiffness can be increased tenfold when the laser power is increased from low to high values. The stiffness gradient within one sample is verified by line scans of Vickers indentations with a nanoindentation system. Then the actuation performance is evaluated for samples with and without stiffness gradients.

MA 28.2 Wed 9:45 POT 6

Magnetic properties of rare-earth-lean $ThMn_{12}$-type (Nd,X)Fe_{11}Ti (X: Y and Ce) compounds: A DFT study — •Stephan Erdmann, Thorsten Klüner, and Halil Ibrahim Sözen — Institute of Chemistry, Carl-von-Ossietzky University of Oldenburg, D-26129 Oldenburg, Germany

Due to the resource criticality of rare-earths (RE), an alternative to the well-known $Nd_2Fe_{14}B$ magnets with a lower amount of critical elements is required. In this work, we performed density functional theory (DFT) calculations to investigate the influence of partial Nd substitution with more abundant elements (X: Y and Ce) in $ThMn_{12}$-type (Nd,X)Fe_{11}Ti compounds. In order to have a systematic understanding, the intrinsic magnetic properties such as saturation magnetization M_S, Curie temperature T_C and magnetocrystalline anisotropy energy, are screened starting from binaries RFe_{12} (R: Y, Ce and Nd). Ti is considered for the thermodynamic stabilization and different concentrations of Ti are taken into account for ternaries $RFe_{12-y}Ti_y$, and quaternaries (Nd,X)$Fe_{12-y}Ti_y$ ($0.5 \leq y \leq 1$). In addition, the effect of nitrogenation is examined for each considered compound. In case of (Nd,Y)Fe_{11}Ti, $|BH|_{max}$ is found to be 384 kJ/m^3 and T_C is calculated to be 595 K. Similarly, $|BH|_{max}$ and T_C are calculated to be 365 kJ/m^3 and 593 K for (Nd,Ce)Fe_{11}Ti magnet, respectively. Both 50 % Nd-lean magnets exhibit higher $|BH|_{max}$ compared to Sm_2Co_{17} and T_C than $Nd_2Fe_{14}B$. For both cases, our theoretical magnetic hardness factor κ is calculated to be 1.20, which qualifies them as good candidates for RE-lean permanent magnets.

MA 28.3 Wed 10:00 POT 6

Ab initio thermodynamic modelling for Ce-based alternative hard magnetic materials — •Halil Ibrahim Sözen[1], Tilmann Hickel[2], and Thorsten Klüner[1] — [1]Institute of Chemistry, Carl-von-Ossietzky University of Oldenburg, D-26129 Oldenburg, Germany — [2]BAM Federal Institute for Materials Research and Testing, 12489 Berlin, Germany

The utilization of the RE-lean $ThMn_{12}$ materials system in combination with the abundant RE element Ce is a promising strategy for modern hard magnet applications. One of the main challenges for the Ce-based hard-magnetic materials is the formation of detrimental Laves phases next to the $ThMn_{12}$-type compound $CeFe_{11}Ti$. In this contribution, we present an ab initio-based approach to modify the stability of these phases in the Ce-Fe-Ti system by additions of 3d and 4d-elements. The results are used to provide two fundamental methodological insights. One of them is our recently developed modeling concept of partial decomposition, which considers the enrichment of the added solutes in phases that would at the considered temperature not be stable in a conventionally used full decomposition model. The second conclusion is the dominant impact of 0 K formation enthalpies on the solute-enhances phase stability compared to finite temperature entropy terms. Based on this, a screening approach is developed, considering the substitution of all 3d and 4d-elements. We show that substituted elements with more than a half-filled 3d-shell or with less than a half-filled 4d-shell mainly reduce the formation temperature of the 1:12 phase.

MA 28.4 Wed 10:15 POT 6

Rare earth lean permanent magnets from computational design and the challenge of the 4f electrons — •H. C. Herper[1], K. P. Skokov[2], S. Ener[2], P. Thunström[1], L. V. B. Diop[3], O. Gutfleisch[2], and O. Eriksson[1,4] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Functional Materials, Department of Material Science, TU Darmstadt, Germany — [3]Université de Lorraine, CNRS, IJL, Nancy, France — [4]School of Science and Technology, Örebro University, Örebro, Sweden

Computational design has been proven to be a powerful tool to tailor properties of functional materials but it becomes challenging in presence of 4f electrons. Here, $NdFe_{11}Ti$ and $YFe_{11}Ti$ serve as prototypes for rare-earth (RE) lean or RE-free magnets with the $ThMn_{12}$ structure. Though, for Sm (Ce) counterparts a core (valence) treatment was sufficient to describe the magnetic properties, the complex low temperature magnetism of $NdFe_{11}Ti$ could only be reproduced with an intermediate sized LDA+U or a DMFT approach (full potential LMTO). We compare our calculations to experimental values obtained from single crystals. The investigations clearly demonstrate the crucial dependence of the calculated magnetic properties of $NdFe_{11}Ti$ on the treatment of the 4f electrons.[1]

Using $Nd_{1-x}Y_xFe_{12-y}Ti1+y$ as a test case we investigated how far the strong dependence of the magnetic properties on the description of the Nd 4f states influences the prediction of new phases.

[1] H.C. Herper et al., Acta Materialia 242, 118473 (2023)

MA 28.5 Wed 10:30 POT 6

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 results based on the in-house developed code MAELAS to determine 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. 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. One of our highlights with this novel approach is an ability to separate exchange-striction (ω_s) from the magnetic part and to avoid the calculation of the paramagnetic state that is still a challenge.

MA 29: Neuromorphic Magnetism / Magnetic Logic

Time: Wednesday 11:30–12:45 Location: HSZ 02

MA 29.1 Wed 11:30 HSZ 02

Brownian Computing Realized Using Skyrmions — •Maarten A. Brems[1], Klaus Raab[1], Grischa Beneke[1], Jan Rothörl[1], Peter Virnau[1], Johan H. Mentik[2], and Mathias Kläui[1] — [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

Reservoir computing (RC) has been considered as one of the key computational principles beyond von-Neumann computing. Magnetic skyrmions, topological particle-like spin textures in magnetic films, are particularly promising for implementing RC since they respond strongly nonlinear to external stimuli and feature inherent multiscale dynamics. We propose and experimentally demonstrate a conceptually new approach to skyrmion computing that combines the RC and Brownian computing [1] concepts. By confining the thermal skyrmion motion [2] that can be electrically gated, we find that already a single skyrmion in a confined geometry suffices to realize non-linearly separable functions, which we demonstrate for the XOR gate along with all other Boolean logic gate operations [3]. Our proposed concept ensures low training costs as well as ultra-low power operation and can be readily extended by including more skyrmions in the reservoir, suggesting high potential for scalable and low-energy reservoir computing. [1] M. A. Brems et al., Appl. Phys. Lett. 119, 132405 (2021). [2] J. Zázvorka et al., Nat. Nanotechnol. 14, 658 (2019). [3] K. Raab, M. A. Brems et al., Nat. Commun. 13, 6982 (2022).

MA 29.2 Wed 11:45 HSZ 02

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 building blocks in the field of neuromorphic computing. In a SMTJ, the magnetic free layer can switch its magnetic orientation induced by thermal activation, leading to a random two-level resistance fluctuations[1]. We show nanosecond fluctuations with dwell times below 10 ns for our inplane magnetized SMTJs. Their intrinsic stochastic behaviour and additional tunability by external magnetic fields, Spin Transfer Torques (STT) or Spin Orbit Torques (SOT) are prerequisites for low-energy artificial neurons in neural networks. True random number generation is demonstrated and evaluated by the statistical test suite from NIST. The probability of a P- (=0) or AP- (=1) state depends on the energy landscape and can be affected by STT. However, the average fluctuation speed is strongly dependend on the temperature. We demonstrate that Joule heating, induced by a large applied current, leads to significantly shorter dwell times. From dwell time measurements, the contributions of STT and Joule heating are extracted.

[1] Hayakawa, K. et al., Phys. Rev. Lett. 126, 117202 (2021).

MA 29.3 Wed 12:00 HSZ 02

Impact of DMI on magnonic antiferromagnetic leaky integrate-and-fire neuronal networks — •Verena Brehm and Alireza Qaiumzadeh — QuSpin, NTNU Trondheim, Norway

Two shifts of paradigms promise to revolutionize modern day computation: First, neuromorphic computing aims to mimic the human brain, which is a fundamentally different approach compared to the state-of-the-art von Neuman computing architecture. Second, antiferromagnetic magnonics promises to be faster and more energy-efficient compared to conventional electronics through avoidance of Joule heating and high-frequency eigenexcitations. We combine both fields and study a proof-of-principle antiferromagnetic spiking neural network, more specifically a leaky integrate-and-fire model both analytically and numerically [1,2].

[1] Johannes W. Austefjord, Verena Brehm, Serban Lepadatu and Alireza Qaiumzadeh: 'Non-volatile leaky integrate-and-fire neurons with domain walls in antiferromagnetic insulators'. http://arxiv.org/abs/2211.16845 (2022).

[2] Even Tønseth, Verena Brehm, Alireza Qaiumzadeh: 'Effects of DMI on spike propagation in neuromorphic systems', to be submitted.

MA 29.4 Wed 12:15 HSZ 02

Light-controlled nanomagnetic logic circuits — •Naëmi Leo[1,2], Matteo Menniti[2], Pieter Gypens[3], Jonathan Leliaert[3], and Paolo Vavassori[2] — [1]CSIC - INMA, Zaragoza, Spain — [2]CIC nanoGUNE BRTA, Spain — [3]Ghent University, Belgium

Magnetic metamaterials with magnetostatically-coupled elements offer an interesting platform to implement low-power and neuromorphic-inspired data processing, in particular when combined with thermally-driven switching processes. By combining nanomagnetic elements with light-controlled plasmonic heaters, here we demonstrate how to design nanomagnetic Boolean OR or AND gates with nanosecond operation. The reconfigurability logic is achieved either by modifying the field protocol setting the initial state or optically, by changing the polarisation and order of the laser pulses exciting the system. Thermoplasmonic-nanomagnetic metamaterials thus lend themselves for the implementation of future fast (up to GHz), energy-efficient (picojoule), and optically-reconfigurable platform for in-memory computation schemes.

MA 29.5 Wed 12:30 HSZ 02

Antiferromagnet-based neuromorphics using dynamics of topological charges — •Shu Zhang — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We propose a spintronics-based hardware implementation of neuromorphic computing, specifically, the spiking neural network, using topological winding textures in one-dimensional antiferromagnets. The consistency of such a network is emphasized in light of the conservation of topological charges, and the natural spatiotemporal interconversions of magnetic winding. We discuss the realization of the leaky integrate-and-fire behavior of neurons and the spike-timing-dependent plasticity of synapses. Our proposal opens the possibility for an all-spin neuromorphic platform based on antiferromagnetic insulators.

MA 30: PhD Focus Session: Non-equilibrium dynamics in theory and experiment

Non-equilibrium phenomena often occur at the edge of phase transitions, for example, in maintaining the organism and cells, photosynthesis, or other exciting reactions. Nevertheless, many of these phenomena are poorly understood or require various disciplines to come together to understand these phenomena in a significant context. Here, however, there is still a need for communication between theory and experiment. Since today's experiments and ideas often have a large gap, we want to use this focus session to create an environment where young researchers can get an overall picture. In doing so, this Ph.D. focus session should emphasize highlights and show the current front of research, in addition to the character of tutorial lectures, and give a chance to conclude in a lively discussion. This PhD Focus Session is organized by Lea Spieker and Gérald Kämmerer (Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Germany).

Time: Wednesday 15:00–18:00 Location: HSZ 02

Invited Talk MA 30.1 Wed 15:00 HSZ 02
Femto- phono- magnetism — •Sangeeta Sharma — Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

From the outset of research into femtomagnetism, the field in which spins are manipulated by light on femtosecond or faster time scales, several questions have arisen and remain highly debated: How does the light interact with spin moments? How is the angular momentum conserved between the nuclei, spin, and angular momentum during this interaction? What causes the ultrafast optical switching of magnetic structures? What is the ultimate time limit on the speed of spin manipulation? What is the impact of nuclear dynamics on the light-spin interaction?

In my talk I will advocate a parameter free ab-initio approach to treating ultrafast light-matter interactions, and discuss how this approach has led both to new answers to these old questions but also to the uncovering of novel and hitherto unsuspected early time spin dynamics phenomena. In particular I will show that selective excitation of phonon modes exert a strong influence on femtosecond demagnetisation. Our finding demonstrates that the nuclear system, typically assumed to play a role of an energy sink aiding remagnetization of the spin system, plays a profound role in controlling femtosecond demagnetization of magnetic materials.

Invited Talk MA 30.2 Wed 15:30 HSZ 02
Spin-switchable molecules in interaction with their environment. — •Cyrille Barreteau — University Paris-Saclay, CEA, CNRS,SPEC, 91191, Gif-sur-Yvette, France

Molecules that can switch spin-state form a very important class of molecules that offers a formidable test bed for fundamental studies and applied research due to the multiple possible channels to tune their properties. Spin-crossover (SCO) molecules are the most common spin-switchable molecules where the spin-state of the metal complex changes under the application of an external stimulus such as light, temperature, pressure etc.. SCO crystals have been the subject of intense studies however; it is much more recent that these molecules have been deposited on surfaces. In practice, the number of SCO that are robust enough to remain intact on surface and retain their switchability is rather limited. In addition, from the modelling point, these systems are also delicate to describe accurately. In this talk, I will present coupled experimental and theoretical results of various spin-switchable molecules that have successfully been deposited on inorganic surfaces. It will be shown how their properties are affected by their environment, in particular we will investigate the role of molecule-molecule and molecule-substrate interaction or the application of an electric field. This will provide us with the tools to manipulate the properties of such systems and give hint for possible strategies to optimize the magneto-transport properties of materials/devices.

15 min. break

Invited Talk MA 30.3 Wed 16:15 HSZ 02
Yep, real photodoping. — Lukas Gierster[1,2] and •Julia Stähler[1,2] — [1]Humboldt-Universität zu Berlin, Inst. f. Chemie, Berlin, Germany — [2]Fritz-Haber-Institut der MPG, Abt. PChem, Berlin, Germany

The advent of photoinduced phase transitions and the investigation of their non-equilibrium dynamics on ultrafast timescales coined various fashionable terms like *hidden phases*, *new phases of matter*, or *photodoping*. They were not always used rigorously and partially developed a life on their own. For instance, a photoexcited solid is not necessarily in a different phase just because it shows different properties than in its ground state - and the pure redistribution of charges after photoexcitation is not equivalent with chemical doping even if the photoexcitation drives a phase transition.

I will discuss these subtle, but important differences using the example of ZnO that undergoes a semiconductor-to-metal transition upon real photodoping at very low excitation densities [1]. Notably, the hidden, metallic phase has no equivalent in the equilibrium phase diagram and shows decay dynamics on ultrafast timescales, but can also be retained and become metastable [2].

[1] Nat. Commun. 12 978 (2021)
[2] Faraday Disc. (2022) DOI:10.1039/D2FD00036A

Invited Talk MA 30.4 Wed 16:45 HSZ 02
Probing ultrafast magnetization thanks to ultrashort soft X-ray pulses — •Emmanuelle Jal — Sorbonne Université, CNRS, Laboratoire de Chimie Physique - Matière et Rayonnement, LCPMR, Paris 75005, France

Even after more than 25 years of studies and debates, the mechanisms of ultrafast demagnetization remain disputed. In order to bring new experimental information into this field, and with the advent of femtosecond X-rays sources, new time-resolved XUV and soft X-ray-based pump/probe techniques are performed on magnetic thin films. During this talk, I will give an overview of what can be done with XUV and soft x-ray short pulses to probe electronic, magnetic, and structural dynamics. A special emphasis will be given to (i) simultaneous electronic and magnetism dynamics [1,2] and (ii) simultaneous structural and magnetism dynamics [3, 4,5].

[1] Rösner et al. Struct. Dyn. 7, 054302 (2020) https://doi.org/10.1063/4.0000033
[2] Hennes et al Appl. Sci. 11m 325 (2021) https://doi.org/10.3390/app11010325
[3] Jal et al. Phys. Rev. B 95, 184422 (2017) https://doi.org/10.1103/PhysRevB.95.184422
[4] Chardonnet et al. Struct. Dyn. 8, 034305 (2021) https://doi.org/10.1063/4.0000109
[5] V. Chardonnet, PhD 2022 https://tel.archives-ouvertes.fr/tel-03864973

45 min. Panel discussion with all speakers

MA 31: Functional Antiferromagnetism II

Time: Wednesday 15:00–17:15 Location: HSZ 04

MA 31.1 Wed 15:00 HSZ 04

Role of substrate clamping on anisotropy and domain structure in the canted antiferromagnet α-Fe2O3 — •Angela Wittmann[1,2], O Gomonay[1], K Litzius[2,3], A Kaczmarek[2], A Kossak[2], D Wolf[4], A Lubk[4], T N Johnson[5], E Tremsina[2], A Churikova[2], F Büttner[6], S Wintz[6], M A Mawass[6], M Weigand[6], F Kronast[6], L Scipioni[7], A Shepard[7], T Newhouse-Illige[7], J A Greer[7], G Schütz[3], N O Birge[2,5], and G S D Beach[2] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Massachusetts Institute of Technology, USA — [3]Max Planck Institute for Intelligent Systems, Germany — [4]Leibniz IFW Dresden, Germany — [5]Michigan State University, USA — [6]Helmholtz-Zentrum Berlin, Germany — [7]PVD Products, USA

Antiferromagnets are at the forefront of research in spintronics. However, many of the underlying phenomena remain to be explored. This work investigates the domain structure in a thin-film canted antiferromagnet α-Fe2O3 in an external magnetic field. Using x-ray magnetic linear dichroism (XMLD) and spin Hall magnetoresistance (SMR) measurements, we find that the internal long-range destressing fields driving the formation of domains do not follow the crystal symmetry of α-Fe2O3 but fluctuate due to substrate clamping [1]. This leads to locally varying effective anisotropy in thin films allowing for the stabilization of long-range complex domain structures. 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. [1] arXiv:2210.16141

MA 31.2 Wed 15:15 HSZ 04

Two-directional electrical switching of insulating antiferromagnetic thin films — •Christin Schmitt[1], Adithya Rajan[1], Grischa Beneke[1], Aditya Kumar[1], Tobias Sparmann[1], Hendrik Meer[1], Rafael Ramos[2], Miguel Angel Niño[3], Michael Förster[3], Eiji Saitoh[2,4], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]WPI-AIMR, Tohoku University, Japan — [3]ALBA Synchrotron Light Facility, Spain — [4]Department of Applied Physics, The University of Tokyo, Japan

Antiferromagnets (AFMs) have gained increasing interest as active elements in spintronic devices due to intrinsic dynamics in the THz range and the absence of stray fields. However, efficient electrical writing and reading is necessary for applications. For insulating antiferromagnets different switching mechanisms based on spin-orbit torques or thermomagnetoelastic effects have been put forward [1,2]. Here, we focus on CoO/Pt thin films where we observe that electrical pulses along the same trajectory can lead to an increase or decrease of the electrical signal, depending on the current density of the pulse. By photoemission electron microscopy (PEEM) employing the x-ray magnetic linear dichroism (XMLD) effect we shed light on this observation and determine whether this is a sign for two competing switching mechanisms or rather some result of the sensitivity distribution of how the electrical measurement is conducted [3]. [1] T. Moriyama, et al., Sci. Rep. 8, 14167 (2018). [2] P. Zhang, et al., Phys. Rev. Lett. 123, 247206 (2019). [3] F. Schreiber, et al., Phys. Rev. Applied 16, 064023 (2021).

MA 31.3 Wed 15:30 HSZ 04

Control and manipulation of antiferromagnetic domains in NiO — •Hendrik Meer[1], Christin Schmitt[1], Olena Gomonay[1], Stephan Wust[2], Paul Herrgen[2], Baerbel Rethfeld[2], Benjamin Stadmüller[1,2], Martin Aeschlimann[2], Jairo Sinova[1], Rafael Ramos[3,4], Lorenzo Baldrati[1], Eiji Saitoh[4,5], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Mainz, Germany — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]CIQUS, Departamento de Quimica-Fisica, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [4]WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan — [5]Department of Applied Physics, The University of Tokyo, Tokyo, Japan

Control of the spin structure is key for the development of future antiferromagnetic spintronic devices. We show how the antiferromagnetic domains of NiO/Pt bilayers can be modified by applying electric currents [1], patterning geometric elements [2], and irradiating with laser light [3]. We image the induced changes in the antiferromagnetic order with synchrotron and lab-based magnetic microscopy. We are able to reveal writing mechanisms for the antiferromagnetic order, laying the foundation for an active role of antiferromagnets in future devices.

[1] H. Meer *et al.*, Nano Lett. **21**, 114 (2021).
[2] H. Meer *et al.*, Phys. Rev. B **106**, 094430 (2022).
[3] H. Meer *et al.*, arXiv:2210.11009 [cond-mat.mtrl-sci] (2022).

MA 31.4 Wed 15:45 HSZ 04

Gate-tunable anomalous Hall effect in an antiferromagnet — Seo-jin Kim[1], Jihang Zhu[2], Mario Piva[1], Marcus Schmidt[1], Dorsa Fartab[1], Andrew Mackenzie[1,3], Michael Baenitz[1], Michael Nicklas[1], Helge Rosner[1], Ashley Cook[1,2], and •Haijing Zhang[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Scottish Universities Physics Alliance, School of Physics and Astronomy, University of St Andrews, St Andrews KY16 9SS, UK

Probing and engineering the magnetic states is a key goal in contemporary condensed matter physics because it can facilitate the understanding of underlying mechanisms of many fundamental physical phenomena, such as the anomalous Hall effect. Here, we report the observation of an anomalous Hall effect in $AgCrSe_2$, a layered triangular lattice metal that lacks inversion symmetry, and has a sizeable antiferromagnetic coupling between Cr spin 3/2 moments in adjacent layers. The anomalous Hall resistivity 3 $\mu\Omega$ cm is comparable to the largest magnitude observed in any antiferromagnetic system to date. We further demonstrate that the anomalous Hall response in thin layer devices can be switched on and off by an ionic gate. We also present the results of an illustrative model that suggests the anomalous Hall effect is driven by Berry curvature that correlates closely with the Rashba spin-orbit coupling. The capability of electrically switching the anomalous Hall effect opens up new avenues for potential voltage controlled spintronic devices.

15 min. break

MA 31.5 Wed 16:15 HSZ 04

In plane magnetic field dependence of anomalous Hall effect in a non-collinear antiferromagnet — •Adithya Rajan[1], Tom Saunderson[1,2], Fabian Lux[1], Dongwook Go[1], Hasan Abdullah[3], Tetsuya Hajiri[4], Hidefumi Asano[4], Udo Schwingenschloegl[3], Yuriy Mokrousov[1,2], and Mathias Klaeui[1] — [1]Institute of Physics, Johannes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, 52424 Jülich, Germany — [3]King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia — [4]Department of Materials Physics, Nagoya University, Nagoya 464-8603, Japan

Non-collinear antiferromagnets (NC-AFM) have attracted much attention recently due to the observation of the anomalous Hall effect (AHE) in these materials [1]. Here we study the AHE as a function of magnetic field direction in the Kagome plane of the antiperovskite nitride Mn3Ni0.35Cu0.65N. We explain the results in the context of irreducible representations of the three-spin unit cell, showing a strong interplay between field dependence of AHE and the octupole moment by fitting to density functional theory calculations. Further, we present non-trivial features in the field dependent AHE loops signifying additional stable spin configurations, and potentially novel transport phenomena. These results open the possibility of a lever through which the spin structure in NC-AFMs can be controlled.

[1] S.Nakatsuji et al., Nature 527, 212 (2015).

MA 31.6 Wed 16:30 HSZ 04

Anomalous Hall Effect in Antiperovskite Nitride Thin Films Driven by Structural Disorder — •Berthold H. Rimmler, Binoy K. Hazra, Holger L. Meyerheim, and Stuart S. P. Parkin — Max Planck Institute of Microstructure Physics, Halle

Antiperovskites display unusual properties such as complex magnetism, superconductivity, negative thermal expansion and distinct magneto-transport effects, which render them interesting for various applications. For instance, Mn-based antiperovskite nitrides, Mn3ZN (Z = Ni, Ga, Sn), have attracted attention in spintronics, as they can host non-collinear antiferromagnetism and other complex magnetic phases. These give rise to unusual intrinsic magneto-transport effects, such as the anomalous Hall effect in absence of magnetization or the spin Hall effect where spin currents display arbitrary spin polarization directions. Control of the antiferromagnetic domain structure in these materials is essential for using these effects in spintronic devices. Therefore, an imbalance of the otherwise fully compensated noncollinear antiferromagnetic textures is required. Previously, strain-driven tetragonal distortion was assumed to be the mechanism allowing for domain control. In this work we show, by comparison of different Mn-based antiperovskite nitrides and using advanced X-ray diffraction measurements, that domain structure control is, instead, enabled by displacements of Mn atoms out of high symmetry positions that locally break the global crystal and magnetic symmetry. We demonstrate that this effect is a general feature of a number of Mn3ZN compounds and might, therefore, also have implications for other antiperovskites.

MA 31.7 Wed 16:45 HSZ 04

Flexomagnetism and vertically graded Néel temperature of antiferromagnetic Cr_2O_3 thin films — •Pavlo Makushko[1], Tobias Kosub[1], Oleksandr Pylypovskyi[1], Natascha Hedrich[2], Jiang Li[1], Alexej Pashkin[1], Stanislav Avdoshenko[3], René Hübner[1], Fabian Ganss[1], Daniel Wolf[3], Axel Lubk[3,4], Maciej Oskar Liedke[1], Maik Butterling[1], Andreas Wagner[1], Kai Wagner[2], Brendan Shields[2], Paul Lehmann[2], Igor Veremchuk[1], Jürgen Fassbender[1], Patrick Maletinsky[2], and Denys Makarov[1] — [1]HZDR, Dresden, Germany — [2]University of Basel, Basel, Switzerland. — [3]IFW Dresden, Dresden, Germany — [4]TU Dresden, Dresden, Germany.

Thin films of antiferromagnetic insulators are a prospective material platform for magnonics, spin superfluidity, THz spintronics, and nonvolatile data storage. Here, we explore the presence of flexomagnetic effects in epitaxial Cr_2O_3 [1]. We demonstrate that a gradient of mechanical strain affects the order-disorder magnetic phase transition, resulting in the distribution of the Néel temperature along the thickness of a Cr_2O_3 film. The inhomogeneous reduction of the antiferromagnetic order parameter induces a flexomagnetic coefficient of about $15\mu B\ nm^{-2}$. The antiferromagnetic ordering in the strained films can persist up to 100°C, rendering Cr_2O_3 as a prospective material for industrial electronics applications.

[1] P. Makushko et al., Nat Commun 13, 6745 (2022).

MA 31.8 Wed 17:00 HSZ 04

Ferromagnetism and Ferroelectricity in a Superlattice of Antiferromagnetic Perovskite Oxides Without Ferroelectric Polarization — •Avijeet Ray, Paresh C. Rout, and Udo Schwingenschlögl — Physical Sciences and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

Using density functional theory with onsite Coulomb interaction, we study the structural, electronic, and magnetic properties of the $SrCrO_3/YCrO_3$ superlattice and their dependence on epitaxial strain. We discover that the superlattice adopts an A-type antiferromagnetic (A-AFM) ordering in contrast to its constituents ($SrCrO_3$: C-AFM; $YCrO_3$: G-AFM) and retains it under compressive strain while becoming ferromagnetic (5 μ_B per formula unit) at +1% strain. The obtained ferroelectric polarization is significantly higher than that of the R_2NiMnO_6/La_2NiMnO_6 (R = Ce to Er) series of superlattices [Nat. Commun. 5, 4021 (2014)] due to a large difference between the antipolar displacements of the Sr and Y cations. The superlattice is a hybrid-improper multiferroic material with a spontaneous ferroelectric polarization (13.5 $\mu C/cm^2$) approaching that of bulk $BaTiO_3$ (19 $\mu C/cm^2$). In addition, the charge-order-driven p-type semiconducting state of the ferromagnetic phase (despite the metallic nature of $SrCrO_3$) is a rare property and interesting for spintronics. Monte Carlo simulations demonstrate a magnetic critical temperature of 90 K for the A-AFM phase without strain and of 115 K for the ferromagnetic phase at +5% strain, for example.

MA 32: Magnetic Imaging Techniques I

Time: Wednesday 15:00–16:30 Location: HSZ 401

MA 32.1 Wed 15:00 HSZ 401

Correlating Magnetic Force Microscopy imaging with bulk Magnetometry for ferroelastic Fe7S8 inspection — •Samuel Seddon[1], Peter Milde[1], Marin Alexe[2], Charles Haines[3], Michael Carpenter[3], and Lukas Eng[1,4] — [1]TU Dresden, Institute of Applied Physics, Noethnitzer Straße 61, 01187 Dresden, Germany — [2]University of Warwick, Coventry, CV4 7AL, England — [3]Universtiy of Cambridge, Cambridge, CB3 0WA, England — [4]ct.qmat: Dresden-Wuerzburg Cluster of Excellence-EXC 2147, TU Dresden, 01062 Dresden

Pyrrhotite, Fe7S8, is a natural mineral exhibiting a strong magnetoelastic coupling - which is to say that the material's ferroelastic domains directly determine the allowed directions of its magnetic moments. This system provides an interesting environment to explore the role that a material's crystal structure has on its magnetic properties, on a unit-cellular level. Here, magnetic force microcopy (MFM) is used to directly correlate local magnetic switching behaviors with various features observed from the bulk magnetic hysteresis; a magnetic hysteresis as acquired from MFM field dependent measurements is visualized. Local magnetic domains thus can be directly correlated to the expected ferroelastic domain wall pinning, as well as to domains that are responsible for the differences observed in saturation magnetization. Preliminary results pertaining to the application of mechanical strain will also be presented.

MA 32.2 Wed 15:15 HSZ 401

Simultaneous Magnetic Field and Field Gradient Mapping of Hexagonal MnNiGa by Quantitative Magnetic Force Microscopy — Norbert H. Freitag[1], Christopher F. Reiche[2], Volker Neu[1], Parul Devi[3], Ulrich Burkhardt[3], Claudia Felser[3], Daniel Wolf[1], Axel Lubk[1], Bernd Büchner[1], and •Thomas Mühl[1] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany — [2]Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT-84112, USA — [3]Max Planck Institute for Chemical Physics of Solids Dresden, 01187 Dresden, Germany

A quantitative, single-pass magnetic force microscopy (MFM) technique is presented that maps one magnetic stray-field component and its spatial derivative at the same time. This technique uses a special cantilever design and a special high-aspect-ratio magnetic interaction tip that approximates a monopole-like moment. Experimental details, such as the control scheme, the sensor design, which enables simultaneous force and force gradient measurements, as well as the potential and limits of the monopole description of the tip moment are discussed. To demonstrate the merit of this technique for studying complex magnetic samples it is applied to the examination of polycrystalline MnNiGa bulk samples. In these experiments, the focus lies on mapping and analyzing the stray-field distribution of individual bubble-like magnetization patterns in a centrosymmetric [001] MnNiGa phase. The results indicate that the magnetic bubbles have a significant spatial extent in depth and a buried bubble top base.

MA 32.3 Wed 15:30 HSZ 401

Quantum calibration of Magnetic Force Microscopy — •Baha Sakar[1], Yan Liu[2], Sibylle Sievers[1], Fedor Jelezko[2], and Hans W. Schumacher[1] — [1]Physikalisch Technische Bundesanstalt — [2]University of Ulm

Magnetic Force Microscopy (MFM) is a magnetic imaging technique that allows to image magnetic structures with nanometer resolution. However, per se it only delivers qualitative information since the magnetic properties of the tip are not known. The only method of obtaining quantitative information from these qualitative data is through a calibration. In this study we report the quantum calibration of a magnetic force microscope (MFM) by measuring the two-dimensional magnetic stray-field distribution of the MFM tip using a single nitrogen vacancy (NV) center in diamond. From the measured stray-field distribution and the mechanical properties of the cantilever a calibration function is derived allowing to convert MFM images to quantum calibrated stray-field maps. This approach overcomes limitations of prior

MFM calibration schemes and allows quantum calibrated nanoscale stray-field measurements in a field range inaccessible to scanning NV magnetometry. Quantum calibrated measurements of a stray-field reference sample allow its use as a transfer standard, opening the road towards fast and easily accessible quantum traceable calibrations of virtually any MFM.

MA 32.4 Wed 15:45 HSZ 401

Controlled surface-modification to revive shallow NV^--centers — •Toni Hache[1,5], Jeffrey N. Neethirajan[1,2,5], Domenico Paone[1,2,5], Dinesh Pinto[1,3], Andrej Denisenko[2], Rainer Stöhr[2], Péter Udvarhelyi[4], Anton Pershin[4], Ádám Gali[4], Jörg Wrachtrup[1,2], Klaus Kern[1,3], and Aparajita Singha[1] — [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 32.5 Wed 16:00 HSZ 401

Deep learning assisted reconstruction of the magnetization from the 2D antiferromagnetic van der Waals material CrSBr — •Riccardo Silvioli, Michele Bissolo, Kartikay Tehlan, Martin Schalk, Ferdinand Menzel, Nathan P. Wilson, Andreas V. Stier, and Jonathan J. Finley — Walter Schottky Institute and TUM School of Natural Sciences, Technische Universität München

We investigate the layered antiferromagnet (AFM) CrSBr, a material with three phase transitions. Order within the layers ($T_{intra} \sim 160K$), order between the layers ($T_N \sim 135K$) and a low T phase close to 40K that is speculated to originate from the ordering of Br vacancies. We use widefield nitrogen vacancy (NV) vector magnetometry to investigate the magnetic phases of this material. We image the 3D magnetic stray field in the plane of the NV centers, located 100nm from the surface of the diamond. Retrieving information on the magnetization (M) from an NV measurement requires reconstruction of M. For out-of-plane M, this is an analytically solvable problem, whereas for in-plane M this problem is ill-posed. We employ a deep learning (DL) approach based on a convolutional neural network (CNN), in order to solve the inverse problem, and determine M from the data. We apply additional constrains to the CNN to follow Maxwells equations by incorporating micro magnetic simulations in the computation of loss during the training phase. We discuss the advantages of this physics informed CNN training approach and compare it to conventional CNN methods as well as reconstruction efforts.

MA 32.6 Wed 16:15 HSZ 401

Magnetic imaging with spin defects in hexagonal boron nitride — Pawan Kumar[1], Florentin Fabre[1], Alrik Durand[1], Tristan Clua-Provost[1], Jiahan Li[2], James H. Edgar[2], Nicolas Rougemaille[3], Johann Coraux[3], Xavier Marie[4], Pierre Renucci[4], Cédric Robert[4], Isabelle Robert-Philip[1], Bernard Gil[1], Guillaume Cassabois[1], •Aurore Finco[1], and Vincent Jacques[1] — [1]Laboratoire Charles Coulomb, Université de Montpellier, CNRS, Montpellier, France — [2]Tim Taylor Department of Chemical Engineering, Kansas State University, Manhattan, Kansas, USA — [3]Université Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France — [4]Université de Toulouse, INSA-CNRS-UPS, LPCNO, Toulouse, France

Optically-active spin defects hosted in hexagonal boron nitride (hBN) are promising candidates for the development of a two-dimensional quantum sensing unit. Here, we demonstrate quantitative magnetic imaging with hBN flakes doped with negatively-charged boron-vacancy ($V_B{}^-$) centers through neutron irradiation [1]. As a proof-of-concept, we image the magnetic field produced by $CrTe_2$, a van der Waals ferromagnet with a Curie temperature slightly above 300 K. The advantages of the hBN-based magnetic sensor described in this work are its ease of use, high flexibility and, more importantly, its ability to be placed in close proximity to a target sample and included in van der Waals heterostructures.

[1] Kumar et al, arXiv 2207.10477 (2022).

MA 33: Frustrated Magnets I

Time: Wednesday 15:00–17:15 Location: HSZ 403

MA 33.1 Wed 15:00 HSZ 403

Frequency-resolved functional renormalization group for quantum magnetic systems — •Janik Potten, Tobias Müller, and Ronny Thomale — Julius-Maximilians-Universität, Würzburg, Deutschland

Strongly correlated materials are one of the most prolific topics of contemporary condensed matter physics. Within this field, the functional renormalization group (FRG) approach for spin models relying on a pseudo-fermionic description has proven to be a very powerful technique in simulating ground state properties of strongly frustrated magnetic lattices. However, the FRG as well as many other theoretical models, suffer from the fact that they are formulated in the imaginary-time Matsubara formalism and thus are only able to predict static correlations directly. Nevertheless, describing the dynamical properties, especially of magnetic systems is one of the fundamental theoretical challenges, as they are the key to bridging the gap to experimental data from neutron scattering experiments. For the pseudo-fermion FRG, we remedy this shortcoming by establishing a methodical approach based on the Keldysh formalism, originally developed to handle non-equilibrium physics. This novel approach allows for calculating the dynamic properties of spin systems on arbitrary lattices. We can identify the correct low-energy behavior of the dynamic spin structure factors for examplary nearest neighbor Heisenberg systems. These first results are promising and extensions of this work might allow for an easy calculation of dynamic properties even for non-equilibrium magnetic systems in the future.

MA 33.2 Wed 15:15 HSZ 403

Spin functional renormalization group for the $J_1J_2J_3$ quantum Heisenberg model — Dmytro Tarasevych, •Andreas Rückriegel, Savio Keupert, Vasilios Mitsiioannou, and Peter Kopietz — Institut für theoretische Physik, Universität Frankfurt

We use our recently developed functional renormalization group (FRG) approach for quantum spin systems to investigate the phase diagram of the frustrated $J_1J_2J_3$ quantum Heisenberg model on a cubic lattice. From a simple truncation of the hierarchy of FRG flow equations for the irreducible spin-vertices which retains only static spin fluctuations and neglects the flow of the four-spin interaction, we can estimate the critical temperature with a similar accuracy as the numerically more expensive pseudofermion FRG. In the regime where the ground state exhibits either ferromagnetic or antiferromagnetic order, a more sophisticated truncation including the renormalization of the four-spin interaction as well as dynamic spin fluctuations reveals the underlying renormalization group fixed point and yields critical temperatures which deviate from the accepted values by at most 4%.

MA 33.3 Wed 15:30 HSZ 403

Thermal Hall conductivity near field suppressed magnetic order in a Kitaev Heisenberg model — •Aman Kumar and Vikram Tripathi — Tata Institute Of Fundamental Research, Mumbai, India

We investigate thermal Hall conductivity κ_{xy} of a J-K Kitaev-Heisenberg model with a Zeeman field in the (111) direction in the light of the recent debate surrounding the possible re-emergence of

Ising topological order (ITO) and half-quantized κ_{xy}/T upon field-suppression of long-range magnetic order in Kitaev materials. We use the purification-based finite temperature Tensor Network approach making no prior assumptions about the nature of the excitations: Majorana, visons or spin waves. For purely Kitaev interactions and fields $h/K \gtrsim 0.02$ sufficient to degrade ITO, the peak κ_{xy}/T monotonously decreases from half-quantization associated with lower fields - a behavior reminiscent of vison fluctuation corrections. In our J-K model (with ferro-K and antiferro-J), in the vicinity of field-suppressed magnetic order, we found κ_{xy}/T to be significant, with peak magnitudes exceeding half-quantization followed by a monotonous decrease with increasing h. We thus conclude that half-quantized thermal Hall effect, if found in our model in the vicinity of field suppressed magnetic order, is a fine-tuning effect and is not associated with a Majorana Hall state with ITO.

MA 33.4 Wed 15:45 HSZ 403

Thermal spin dynamics of Kitaev magnets — •Oliver Franke — Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Deutschland

The honeycomb magnet α-$RuCl_3$ is a prime candidate material for realizing the Kitaev quantum spin liquid (QSL), but it shows long-range magnetic order at low temperature. Nevertheless, its broad inelastic neutron scattering (INS) response at finite frequency has been interpreted as that of a 'proximate QSL'. A moderate magnetic field indeed melts the residual zigzag order, giving rise to peculiar intermediate field phases before the high-field polarized state.

Are the scattering continua observed in experiments signatures of quantum fractionalized excitations in a QSL phase? Or are they caused by thermal fluctuations that break the large unit cell intermediate field phases predicted by theory? In this talk, I will present our recent study on the subject, which helps to answer these topical questions and highlights the importance of distinguishing finite temperature fluctuations from genuine quantum fractionalization signatures in frustrated magnets.

15 min. break

MA 33.5 Wed 16:15 HSZ 403

Disorder effects in the Kitaev-Heisenberg model — •Ayushi Singhania[1], Jeroen van den Brink[1,2], and Satoshi Nishimoto[1,2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [2]Department of Physics, Technical University Dresden, 01069 Dresden, Germany

We study the interplay of disorder and Heisenberg interactions in Kitaev model on honeycomb lattice. The effect of disorder on the transition between Kitaev spin liquid and magnetic ordered states as well as the stability of magnetic ordering is investigated. Using Lanczos exact diagonalization we discuss the consequences of two types of disorder: random-coupling disorder & singular-coupling disorder. They exhibit qualitatively similar effects in the pure Kitaev-Heisenberg model without long-range interactions. The range of spin liquid phases is reduced and the transition to magnetic ordered phases becomes more crossover-like. Furthermore, the long-range zigzag and stripy orderings in the clean system are replaced by their three domains with different ordering direction. Especially in the crossover range the coexistence of magnetically ordered and Kitaev spin-liquid domains is possible. Surprisingly, in presence of long range interactions, the stability of magnetic ordered state is diminished by singular-coupling disorder, and accordingly, the range of spin-liquid regime is extended. This mechanism may be relevant to materials like α-RuCl3 and H3LiIr2O6 where the zigzag ground state is stabilized by weak long-range interactions. We also find that the flux gap closes at a critical disorder strength and vortices appears in the flux arrangement.

MA 33.6 Wed 16:30 HSZ 403

$ZnCr_2Se_4$ as a spiral-spin-liquid approximant — •D. S. Inosov[1], Y. V. Tymoshenko[1], A. Akopyan[2], D. Shukla[2], N. Prasai[2], M. Doerr[1], D. Gorbunov[3], S. Zherlitsyn[3], D. J. Voneshen[4,5], M. Boehm[6], V. Tsurkan[7,8], V. Felea[8], A. Loidl[7], Y. O. Onykiienko[1], J. Ollivier[6], and J. L. Cohn[2] — [1]IFMP, TU Dresden — [2]University of Miami, Florida, USA — [3]Hochfeld-Magnetlabor Dresden-Rossendorf — [4]ISIS Facility, RAL, Didcot, UK — [5]Royal Holloway University of London, UK — [6]Institut Laue-Langevin, Grenoble, France — [7]Institute of Physics, University of Augsburg — [8]Institute of Applied Physics, Chisinau, Moldova

We investigated the cubic spinel helimagnet $ZnCr_2Se_4$ in its single-domain spin-spiral state by a combination of neutron scattering, thermal conductivity, ultrasound velocity, and dilatometry measurements. In zero magnetic field, the magnon spectrum consists of conventional gapless Goldstone modes and soft pseudo-Goldstone modes with a small energy gap of $\sim$0.17 meV. In an applied magnetic field, this gap closes nonmonotonically, so that upon reaching a critical field of 6 T, the gap vanishes over a whole 2D manifold in the reciprocal space. This was recently identified as a prerequisite for a putative spiral-spin-liquid ground state [see S. Gao *et al.*, Phys. Rev. Lett. **129**, 237202]. This highly unusual behavior of the spin gap causes large anomalies in thermal conductivity at subkelvin temperatures — nearly two orders of magnitude below the Néel temperature. Our results apply to a broad class of centrosymmetric Heisenberg helimagnets where discrete lattice symmetry is spontaneously broken by the magnetic order.

MA 33.7 Wed 16:45 HSZ 403

Magneto-elastic coupling and new phases in the Shastry-Sutherland compound NdB_4 discovered by high-resolution dilatometry — •Rahel Ohlendorf[1], Sven Spachmann[1], Lukas Fischer[1], Daniel Brunt[2], Jasper Linnartz[3], Steffen Wiedmann[3], Geetha Balakrishnan[2], Oleg Petrenko[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Department of Physics, University of Warwick, Coventry, UK — [3]HFML Nijmegen, Netherlands

We report high-resolution dilatometry studies on single crystals of the Shastry-Sutherland-lattice magnet NdB4 supported by specific heat and magnetometry data. The evolution of magnetically ordered phases below $T_N = 17.2$ K (commensurate antiferromagnetic phase), $T_{IT} = 6.8$ K (intermediate incommensurate phase), and $T_{LT} = 4.8$ K (low-temperature phase) is associated with pronounced anomalies in the thermal expansion coefficients. The data imply significant magneto-elastic coupling and evidence of a structural phase transition at T_{LT}. Grüneisen analysis of the ratio of thermal expansion coefficient and specific heat enables the derivation of uniaxial as well as hydrostatic pressure dependencies. From the observed anomalies the magnetic phase diagrams for B||c up to 15 T and for B||[110] up to 35 T are constructed. New in-field phases are discovered for both field directions and already known phases are confirmed. In particular, phase boundaries are unambiguously shown by sign changes of observed anomalies and corresponding changes in uniaxial pressure effects.

MA 33.8 Wed 17:00 HSZ 403

Emergent U(1) symmetry due to off-diagonal symmetric exchange interactions — •Sagar Ramchandani, Ciarán Hickey, and Simon Trebst — Institute for Theoretical Physics, University of Cologne, Germany

Frustrated magnetic systems are a result of competing interactions. These systems are of interest as they can exhibit a large ground state degeneracy, sometimes in the form of an emergent symmetry for the ground state.

Here, we study the effects of off-diagonal symmetric exchange interactions on classical O(3) spins on the Kagome lattice. We find an emergent U(1) symmetry in the ground state. We study the critical properties and the influence of thermal order-by-disorder on this symmetry using a combination of analytical and Monte Carlo methods.

The symmetry can be understood on the level of a single triangle. Using this understanding, we also propose a set of rules to generate a lattice model with these off-diagonal interactions that will exhibit the same emergent U(1) symmetry. The rules combine N triangles exhibiting N*U(1) symmetries into a single U(1) symmetry. These lattices can be generated in 1D, 2D & 3D.

MA 34: Focus Session: Spin-Phonon Coupling

Recent work on ultrafast demagnetization in ferromagnets has demonstrated that angular momentum can be transferred from the spin system to the lattice on ultrashort time scales. These findings demonstrate that a detailed understanding of the mechanisms that transfer angular momentum between the spin system and the lattice are of key importance in spintronics. The goal of this focus session is to give an overview over spin-phonon coupling effects in solids, ranging from the Einstein-de Haas effect on ultrafast time scales to magnon-phonon coupling and acoustic spin pumping at GHz frequencies. Coordinators: Tobias Kampfrath, Freie Universität Berlin and Uli Nowak, Universität Konstanz.

Time: Thursday 9:30–13:00 Location: HSZ 02

Invited Talk MA 34.1 Thu 9:30 HSZ 02
Polarized phonons carry angular momentum in ultrafast demagnetization — •Peter Baum — Universität Konstanz, Germany

Many laser-excited magnetic materials lose their magnetic order almost completely within femtosecond timescales, but where is the missing angular momentum in such a short time? Here we use ultrafast electron diffraction with THz-compressed electron pulses to reveal in nickel an almost instantaneous, long-lasting, non-equilibrium population of anisotropic high-frequency phonons with an anisotropy plane that is perpendicular to the direction of the initial magnetization. We explain these observations by means of circularly polarized phonons that quickly absorb the angular momentum of the spin system before macroscopic sample rotation. The time that is needed for demagnetization is related to the time it takes to accelerate the atoms. These results provide an atomistic picture of the Einstein-de Haas effect and signify the general importance of polarized phonons for non-equilibrium dynamics and phase transitions.

Invited Talk MA 34.2 Thu 10:00 HSZ 02
Spin-phonon coupling in ordered magnets: origin and consequences — •Akashdeep Kamra — Universidad Autónoma de Madrid, Madrid, Spain

Interaction between the spin and lattice degrees of freedom in magnets underlies a broad range of phenomena from magnetic damping to the Einstein-de Haas effect. Despite its long history and high importance, an adequate understanding of spin-phonon coupling's origin and potential consequences have eluded us. In this talk, we will discuss the microscopic mechanisms and related symmetry-breaking that underlie the spin-phonon coupling thereby achieving guidance on how to engineer it. In this discussion, we will pay special attention to the rotational invariance or total angular momentum conservation and how to account for it in the simulation of coupled spin and lattice dynamics. Then, we will examine some of the direct consequences of this coupling, focusing on magnon-polaron formation in ferro and antiferromagnets as well as the Einstein-de Haas effect in magnetic nanoparticles. If time permits, we will briefly discuss future directions and challenges.

References:
[1] M. Weißenhofer et al., arXiv:2211.02382.
[2] H. T. Simensen et al., Phys. Rev. B 99, 064421 (2019).
[3] A. Kamra et al., Phys. Rev. B 91, 104409 (2015).

Invited Talk MA 34.3 Thu 10:30 HSZ 02
Magnon-mechanics in high overtone acoustic resonators — •Hans Huebl — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — School of Natural Sciences, Technische Universität München, Garching, Germany — 3Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Magnetoelastic coupling between excitation modes of the spin system (spin waves) and the lattice (phonons) is of interest from a fundamental perspective and can enable mode hybridization. For quantum sensing and transduction protocols, excitation exchange between the magnetic and elastic systems is of importance, however typically this requires strong coupling between the modes. In this presentation, I will present our current results on coupling the magnetization dynamics of a Kittel mode to a high-overtone bulk acoustic resonator and discuss this hybrid system in the context of sensing and transduction.

15 min. break

Invited Talk MA 34.4 Thu 11:15 HSZ 02
Cavity Magnomechanics: Harnessing the Magnomechanical Coupling for Applications in the Microwave and Optical Regimes — •Silvia Viola Kusminskiy — Institute for Theoretical Condensed Matter, RWTH Aachen University, 52074 Aachen, Germany — Max Planck Institute for the Science of Light, Staudtstr. 2 91058 Erlangen, Germany

Cavity magnonic systems are ideally suited to explore the range of possibilities opened by tailoring the interactions between photons, phonons, and magnons. In this talk I will discuss the different coupling mechanisms and propose applications ranging from quantum thermometry to wavelength conversion.

Invited Talk MA 34.5 Thu 11:45 HSZ 02
Coherent spin-wave transport in an antiferromagnet — •Andrea Caviglia — Department of Quantum Matter Physics, University of Geneva, 24 Quai Ernest Ansermet, CH-1211 Geneva, Switzerland

Magnonics is a research field complementary to spintronics, in which the quanta of spin waves replace electrons as information carriers, promising lower dissipation. The development of ultrafast, nanoscale magnonic logic circuits calls for new tools and materials to generate coherent spin waves with frequencies as high and wavelengths as short as possible. Antiferromagnets can host spin waves at terahertz frequencies and are therefore seen as a future platform for the fastest and least dissipative transfer of information. However, the generation of short-wavelength coherent propagating magnons in antiferromagnets has so far remained elusive. Here we report the efficient emission and detection of a nanometre-scale wavepacket of coherent propagating magnons in the antiferromagnetic oxide dysprosium orthoferrite using ultrashort pulses of light. The subwavelength confinement of the laser field due to large absorption creates a strongly non-uniform spin excitation profile, enabling the propagation of a broadband continuum of coherent terahertz spin waves. The wavepacket contains magnons with a shortest detected wavelength of 125nm that propagate into the material with supersonic velocities of more than 13kms-1. This source of coherent short-wavelength spin carriers opens up new prospects for terahertz antiferromagnetic magnonics and coherence-mediated logic devices at terahertz frequencies.

MA 34.6 Thu 12:15 HSZ 02
Magnon-phonon coupling in polycrystalline metallic thin films — •Manuel Müller[1,2], Johannes Weber[1,2], Fabian Engelhardt[3,4,5], Victor A. S. V. Bittencourt[3,6], Thomas Luschmann[1,2,7], Silvia Viola Kusminskiy[5,3], Stephan Geprägs[1], Rudolf Gross[1,2,7], Matthias Althammer[1,2], and Hans Huebl[1,2,7] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]TUM School of Natural Sciences, Technische Universität München, Garching, Germany — [3]Max Planck Institute for the Science of Light, Erlangen, Germany — [4]Department of Physics, University Erlangen-Nuremberg, Erlangen, Germany — [5]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [6]ISIS (UMR 7006), Université de Strasbourg, 67000 Strasbourg, France — [7]Munich Center for Quantum Science and Technology (MCQST), Munich, 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 is of interest for future applications, such as microwave-to-optics transducers and phononic spin valve devices. As a finite magnetoelastic coupling affects the magnetization dynamics of the magnetic layer, it can be characterized with high sensitivity using ferromagnetic resonance spectroscopy. By using broadband ferromagnetic resonance spectroscopy, we have studied study the magnetoelastic coupling between silicon and sapphire substrates and ferromagnetic thin films deposited on them via DC sputtering.

MA 34.7 Thu 12:30 HSZ 02

Parametric excitation and instabilities of spin waves driven by surface acoustic waves — •Moritz Geilen[1], Roman Verba[2], Alexandra Nicoloiu[3], Daniele Narducci[4], Adrian Dinescu[2], Milan Ender[1], Morteza Mohseni[1], Florin Ciubotaru[4], Mathias Weiler[1], Alexandru Müller[3], Burkard Hillebrands[1], Christoph Adelmann[4], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern Landau, Germany — [2]Institute of Magnetism, Kyiv, Ukraine — [3]National Institute for Research and Development in Microtechnologies, Bucharest, Romania — [4]imec, Leuven, Belgium

We present our experimental results on the parametric excitation of spin waves by coherent surface acoustic waves in metallic magnetic thin film structures. The involved magnon modes are analyzed with micro-focused Brillouin light scattering spectroscopy and complementary micromagnetic simulations combined with analytical modelling to determine the origin of the spin-wave instabilities. Depending on the experimental conditions, we observe spin-wave instabilities originating from different phonon-magnon and magnon-magnon scattering processes. Our results demonstrate that an efficient excitation of high amplitude, strongly nonlinear magnons in metallic ferromagnets is possible by surface acoustic waves, which opens novel ways to create micro-scaled nonlinear magnonic systems for logic and data processing.

We acknowledge financial support by EU via EU Horizon 2020 (contract no.801055) and ERC Starting Grant No. 101042439.

MA 34.8 Thu 12:45 HSZ 02

Magnetic ordering and spin-lattice interactions in MCrO$_2$ and MCrS$_2$ (with M = Li, Na, K, Cu, Ag, Au) — •S. Mankovsky, H. Lange, S. Polesya, and H. Ebert — Department Chemie, Ludwig Maximilian University, Munich, Germany

The triangular lattice antiferromagnets (TLA) are discussed in the literature as materials exhibiting a variety of magneto-elastic and magneto-electric properties determined by a complex magnetic structure driven by magnetic frustrations. In the present work we have investigated two groups of TLA compounds, MCrO$_2$ and MCrS$_2$, with M = Li, Na, K, Cu, Ag, Au. Their properties are discussed on the basis of first-principles calculations of their electronic structure as well as exchange coupling and spin-lattice coupling (SLC) parameters. The properties of these two groups are expected to be quite different, among others, because of a different distance dependency of the Cr-Cr exchange interactions. In particular one finds that the Cr layers in MCrS$_2$ cannot be treated as independent, in contrast to MCrSO$_2$ with quasi-2D frustrated AFM Cr layers. We discuss different contributions to the magnon-phonon interaction responsible for a modification of the phonon spectra in these materials, as well as a transition to the AFM state in some of them, accompanied by a lattice distortion as observed by experiment. In addition, a contribution of the inverse Dzyaloshinskii-Moriya (DM) interaction mechanism [PRL **95**, 057205 (2005)] to the ferroelectric properties driven by the magnetic ordering is discussed on the basis of the calculated DM-SLC parameters.

MA 35: Skyrmions III

Time: Thursday 9:30–12:00 Location: HSZ 04

MA 35.1 Thu 9:30 HSZ 04

Skyrmion dynamics and applications — •Ismael Ribeiro de Assis, Ingrid Mertig, and Börge Göbel — Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Skyrmionics and neuromorphics are among the most promising fields of physics with the perspective of creating future devices and technologies. Magnetic skyrmions are nanoscale magnetic whirls that are topologically protected and can be moved by currents, leading to the prediction of several applications. Its topological charge leads to high stability; however, it also leads to the skyrmion Hall effect. From memory storage devices, like the racetrack memory [1], to computing devices, like artificial neurons[2,3], this shortcoming is one of the primary reasons why skyrmion-based spintronic devices have yet to be achieved. Here, we study the motion of skyrmions with different topological charges and helicities. Using an effective center-of-mass description of these magnetic quasiparticles, namely, the Thiele equation, we analyze their dynamics under different gradient landscapes and interactions aiming to suppress or take advantage of the skyrmion Hall effect. Additionally, we discuss possible applications in neuromorphic computing. [1] A. Fert et al., Nature Nanotechnology 8, 152-156(2013) [2] S. Li et al., Nanotechnology 28, 31LT01 (2017) [3] I.R. de Assis et al., arXiv preprint arXiv:2209.11017 (2022).

MA 35.2 Thu 9:45 HSZ 04

Moving Antiferromagnetic Skyrmions with Spin Waves — •Michael Lau[1,2], Wolfgang Häusler[3], and Michael Thorwart[1,2] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg — [3]Institute of Physics, University of Augsburg

The possibility to move magnetic Skyrmions opens the pathway of technical applications in the form of nanoscale information carriers. While it is well-studied for ferromagnetic materials that spin waves are able to move Skyrmions, driving antiferromagnetic Skyrmions with spin waves is a relatively new topic. We present simulations on a two-dimensional lattice, with classical magnetic moments on each site, which reveal that antiferromagnetic Skyrmions can be accelerated by spin waves injected at one edge of the lattice. We consider in detail various forms of spin waves and draw connections between Skyrmion behavior and the spin wave attributes. To this end we analytically and numerically investigate classical antiferromagnetic spin waves at first. We derive a consistent analytical description of circularly- and linearly polarized spin waves and the two modes of each polarization. Using this knowledge we investigate their impact on the Skyrmion and show that the symmetries of the spin wave modes is reflected in the resulting Skyrmion motion. One example is the non-vanishing Skyrmion Hall effect for circularly polarized spin waves. It turns out that also frequency and amplitude of the spin waves significantly influence the Skyrmion motion.

MA 35.3 Thu 10:00 HSZ 04

Geometry-induced motion of magnetic skyrmions in curved ferro- and antiferromagnetic films — •Kostiantyn V. Yershov[1,2], Attila Kákay[3], and Volodymyr P. Kravchuk[2,4] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Germany — [4]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, Germany

Here, we present the effect of the spontaneous drift of a magnetic skyrmion in curved films under the action of the curvature gradients without any external stimuli [1]. The strength of the curvature-induced driving is determined by the type of the intrinsic Dzyaloshinskii–Moriya interaction, while the trajectory is determined by the type of magnetic ordering: ferro- or antiferromagnetic. Using rigid particle approximation, we show that for the case of Néel skyrmion the driving force is linear with respect to the gradient of the curvature, while for Bloch skyrmion the driving is proportional to the product of mean curvature and its gradient. During the motion along the surface, skyrmion experiences deformation which depends on the skyrmion type. Equations of motion for Néel and Bloch magnetic skyrmions in curved ferromagnetic and antiferromagnetic materials are obtained in terms of collective variables. [1] K. Yershov et al, PRB **105** (2022), 054425.

MA 35.4 Thu 10:15 HSZ 04

Non-equilibrium dynamics of quantum skyrmion upon projective measurements — •Fabio Salvati, Andrey Bagrov, Tom Westerthout, and Mikhail I. Katsnelson — Institute for Molecules and Materials, Radboud University, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

Magnetic skyrmions are particle-like spin structures characterized by nanometer size and long lifetime. These remarkable properties make them a promising candidate for the role of information carriers in magnetic information storage and processing devices.

Although considerable progress has been made in studying skyrmions in classical systems, little is known about skyrmions in quantum systems, since the quantum skyrmion state cannot be directly observed probing the local magnetization of the system. A characterization is possible using the scalar chirality - a particular local three-spin correlation function defined on neighboring lattice sites - as a quantum analog of the skyrmionic topological index.

In our work, we use the scalar chirality to investigate the local dynamics of a quantum skyrmion on a triangular lattice, following a projective measurement. Findings reveal the robustness of the quantum skyrmion state supported by spin waves. Besides we identify a feature to detect experimentally quantum skyrmions, performing the analysis of the Fourier transform of the spin-spin correlation function.

MA 35.5 Thu 10:30 HSZ 04

Nonlinear dynamics of skyrmion strings — •Volodymyr Kravchuk[1,2] and Markus Garst[1] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, 03143 Kyiv, Ukraine

A skyrmion core, percolating the magnet volume, forms a skyrmion string – the topological Dirac string-like object. Here we analyze the nonlinear dynamics of a skyrmion string in a low-energy regime by means of the collective variables approach generalized for the case of strings. Using the perturbative method of multiple scales (both in space and time), we show that the weakly nonlinear dynamics of the translational mode propagating along the string is captured by the Nonlinear Schrödinger equation of the focusing type. As a result, the fundamental helix-shaped "planar-wave" solution experiences modulational instability, which leads to the formation of cnoidal waves. Both types of cnoidal waves, dn- and cn-waves, as well as the separatrix soliton solution [1], are confirmed by the micromagnetic simulations. Beyond the class of the traveling-wave solutions, we found Ma-breather propagating along the string. Finally, we proposed a generalized approach, which enables one to describe nonlinear dynamics of the modes of different symmetries, radially symmetrical, elliptical, etc.

[1] V.P. Kravchuk, U.K. Rößler, J. van den Brink, M. Garst, Phys. Rev. B 102, 220408(R) (2020).

15 min. break

MA 35.6 Thu 11:00 HSZ 04

Manipulation of Skyrmion Helicity in Frustrated Magnets — •Ross Knapman[1,2], Timon Tausendpfund[1], Sebastián A. Díaz[2], and Karin Everschor-Sitte[2,3] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany — [3]Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Aside from the well-studied mechanisms of the stabilisation of magnetic skyrmions via the Dzyaloshinskii-Moriya interaction, skyrmions can be stabilised with magnetic frustration. [1] In such a system, the helicity becomes a degree of freedom which can be manipulated using externally-applied electric and magnetic fields. [2,3] In our work, we use a Ginzburg-Landau description of the system [4] to model the dynamics of the skyrmion using analytical and numerical approaches. In tuning in the time dependences of the electric and magnetic fields, we can manipulate the energy landscape to induce interesting phenomena, including helicity rotations.

[1] Okubo, T., Chung, S., Kawamura, H., Phys. Rev. Lett. **108**, 017206 (2012)

[2] Y., X., Chen, J., Dong, S., New J. Phys. **22**, 083032 (2020)

[3] Psaroudaki, C., Panagopoulos, C., Phys. Rev. Lett. **127**, 067201 (2021)

[4] Lin, S. Z., Hayami, S., Phys. Rev. B **93**, 064430 (2016)

MA 35.7 Thu 11:15 HSZ 04

Non-synthetic antiferromagnetic multi-meronic Néel spin-textures in thin films — •Amal Aldarawsheh[1,2], Moritz Sallermann[1,3,4], Muayad Abusaa[5], 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]RWTH Aachen University, 52056 Aachen, Germany — [4]Science Institute and Faculty of Physical Sciences, University of Iceland, VR-III, 107 Reykjavík, Iceland — [5]Arab American University, Jenin, Palestine

The realization of topological antiferromagnetic (AFM) solitons in real materials is a major goal towards their use in information technology. In contrast to their ferromagnetic version, they are expected to be insensitive to the Hall effect and dipolar interactions. Here, based on density functional theory in conjunction with atomistic spin dynamics, we predict the emergence in a triangular lattice of complex Néel AFM vortex-antivortex structures in transition metallic thin films interfaced with Ir and Pd layers. These topological structures are intrinsic, i.e. they form in a single AFM material, but are different from the recently predicted intrinsic AFM skyrmions [1]. They can carry various topological charges and can combine in hexameronic or dodecameronic textures, which can show enhanced stability with respect to external magnetic field depending on the electronic nature of the interfaces. [1] A. Aldarawsheh et al., ArXiv:2202.12090 (2022). Work funded by the PGSB (BMBF-01DH16027) and DFG (SPP 2137; LO 1659/8-1).

MA 35.8 Thu 11:30 HSZ 04

Investigation of the stability of exchange-stabilized skyrmions — •Sarina Lebs[1], Markus Hoffmann[1], Moritz Sallermann[1,2], and Stefan Blügel[1] — [1]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, Jülich, Germany — [2]Science Institute of the University of Iceland, VR-III, Reykjavík, Iceland

To utilize magnetic skyrmions, localized topologically nontrivial textures, in technological applications, a long lifetime at room temperature is required. Therefore, a major focus of magnetism research is the analysis of the stability of such skyrmions. The main focus in the past was on DMI-stabilized skyrmions, little is known about exchange stabilized ones.

In this presentation, we discuss the significance of the different stabilization mechanisms for the skyrmion lifetimes. Using the Spirit code [1], we perform LLG, GNEB, as well as HTST simulations to calculate skyrmion profiles, transition paths, and lifetimes for both DMI- as well as exchange-stabilized skyrmions. We discuss similarities as well as differences between the stabilization mechanisms for the lifetime.

We acknowledge funding by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant No. 856538, project 3D MAGiC).

[1] `Spirit` – spin simulation framework, https://spirit-code.github.io

MA 35.9 Thu 11:45 HSZ 04

Lifetime of coexisting sub-10 nm zero-field skyrmions and antiskyrmions — •Moritz A. Goerzen[1], Stephan von Malottki[1,2,3], Sebastian Meyer[1,4], Pavel F. Bessarab[2,5], and Stefan Heinze[1] — [1]ITAP, University of Kiel, Germany — [2]Science Institute of the University of Iceland, Iceland — [3]Thayer School of Engineering, Dartmouth College, USA — [4]Nanomat/Q-mat/CESAM Université de Liège, Belgium — [5]Department of Physics and Electrical Engineering, Linnaeus University, Sweden

Localized spin structures such as magnetic skyrmions have raised high hopes for future spintronic devices. For many applications it can be of great advantage to have more than one particle-like texture available. The coexistence of skyrmions and antiskyrmions has been proposed in inversion symmetric magnets with exchange frustration. However, so far only model systems have been discussed and the interplay with the Dzyaloshinskii-Moriya interaction (DMI) has not been studied. Here, we predict that skyrmions and antiskyrmions with diameters below 10 nm can coexist at zero magnetic field in a Rh/Co bilayer on the Ir(111) surface. Based on an atomistic spin model parameterized from density functional theory, we show that the lifetimes of metastable skyrmions and antiskyrmions in the ferromagnetic ground state are above one hour for temperatures up to 75 K and 48 K, respectively. The entropic contribution to nucleation and annihilation rates is different for skyrmions and antiskyrmions. This opens the route to thermal control of coexisting skyrmions and antiskyrmions in frustrated magnets with DMI.

MA 36: Magnetic Particles / Clusters

Time: Thursday 9:30–11:00 Location: HSZ 401

MA 36.1 Thu 9:30 HSZ 401

Magnetic properties of metastable single-crystalline cobalt iron oxide nanoflakes investigated by Mössbauer spectroscopy
— Soma Salamon[1], Joachim Landers[1], •Anna Rabe[1,2], Franz-Philipp Schmidt[3], Thomas Lunkenbein[3], Malte Behrens[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Institute of Inorganic Chemistry, Kiel University — [3]Department of Inorganic Chemistry, Fritz Haber Institute of the Max Planck Society

Spinel-type transition metal oxides are of high interest for a variety of applications, including heterogeneous catalysis, energy conversion and magnetic materials with fine-tuned properties. The compound Co_2FeO_4 is of particular interest, but its phase diagram contains a large immiscibility. Using Mössbauer spectra recorded at low temperatures (4.3 K) and high magnetic fields (10 T), we were able to precisely determine the distribution of Fe ions across tetrahedral and octahedral sites. This enabled us to characterize the influence of different calcination temperatures from 400 °C up to 900 °C on the phase composition and miscibility, while also providing valuable insights on the temperature dependent evolution of the spectral hyperfine structure. These findings were successfully correlated with results from magnetometry, showing clear signs of a change in magnetic properties based on different degrees of intermixing, interface area, and phase separation, as also supported by TEM and EDX measurements. Financial support by the German Research Foundation (DFG) via the CRC/TRR 247 (Project-ID 388390466, sub-project B02) is gratefully acknowledged.

MA 36.2 Thu 9:45 HSZ 401

Mössbauer spectroscopy study of anisotropic barium ferrite hybrid systems
— •Juri Kopp[1], Joachim Landers[1], Soma Salamon[1], Benoît Rhein[3], Hajnalka Nádasi[2], Darja Lisjak[4], Patricija Hribar Boštjančič[4], Alenka Mertelj[4], Alexey Eremin[2], Annette Schmidt[3], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Department of Nonlinear Phenomena, Institute for Experimental Physics, Otto von Güricke University Magdeburg — [3]Department of Chemistry, Physical Chemistry, University of Cologne — [4]Department of Complex Matter, Jožef Stefan Institute

Using anisotropic barium ferrite nanoplatelets in liquid or liquid crystalline (LC) environments, we obtain ferrofluids with anisotropic properties such as nematic formation of the platelets or a magneto-responsive LC system. The aim of this work is to study magnetic hybrid systems with temperature- and field-dependent Mössbauer spectroscopy, which gives us access to the diffusion processes of the particles via line broadening, and to the magnetic orientation behavior based on relative line intensity ratios. As barium ferrite exhibits a rather complex crystal structure, we use reference data of powder samples in order to investigate each individual iron sublattice position of this system. In an approach to analyze anisotropic diffusion and alignment processes more efficiently, spectra are recorded with gamma incidence direction perpendicular and parallel relative to the applied magnetic field. This work is supported by the DFG (LA5175/1-1.).

MA 36.3 Thu 10:00 HSZ 401

High throughput analysis of surface-functionalized superparamagnetic particles in dynamic magnetic field landscapes
— •Yahya Shubbak[1,2], Rico Huhnstock[1,2], Kristina Dingel[2,3], Bernhard Sick[2,3], and Arno Ehresmann[1,2] — [1]Institute of Physics & Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, D-34132 Kassel — [2]AIM-ED - Joint Lab Helmholtzzentrum für Materialien & Energie, D-14109 Berlin — [3]Intelligent Embedded Systems, University of Kassel, D-34121 Kassel

The precise manipulation of magnetic micro- and nano-particles in microfluidic environments opens new avenues for investigations of biomolecular analyte detection and interactions.[1] Motion control schemes based on a combination of static magnetic field landscapes superposed with external magnetic field pulses enable translatory motion control of magnetic particles at the nanoscale over macroscopic distances.[3] Here we demonstrate a novel method harnessing AI-enhanced fully-automated optical recognition algorithms [4] to analyze changes in the motion behaviour of such particles due to liquid mediated surface to surface (particle to substrate) interaction.

[1] Lim, B., Vavassori, P., Sooryakumar, R. & Kim, C. Nano/microscale magnetophoretic devices for biomedical applications. J. Phys. D: Appl. Phys. 50, 33002 (2017) [2]Lin, G., Makarov, D. & Schmidt, O. G. Magnetic sensing platform technologies for biomedical applications. Lab on a chip 17, 1884-1912 (2017) [3]Issadore, D. et al. Magnetic sensing technology for molecular analyses. Lab on a chip 14, 2385-2397

MA 36.4 Thu 10:15 HSZ 401

Reversible on-chip focusing and clustering of superparamagnetic beads using engineered magnetic domain patterns
— •Rico Huhnstock[1], Lukas Paetzold[1], Maximilian Merkel[1], Piotr Kuświk[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Institute of Molecular Physics, Polish Academy of Sciences, M. Smoluchowskiego 17, Poznań 60-179, Poland

To realize fast and reliable point-of-care medical diagnostics, incorporating magnetic particles into a Lab-on-a-chip technology platform is considered promising. For sensitive detection, binding of the analyte species to surface-functionalized particles and subsequent formation of particle aggregates with the analyte acting as molecular bridges is a possible route [1]. As close proximity between particles is required for this scheme, we demonstrate in this work a locally defined focusing of superparamagnetic microparticles within an aqueous medium above a magnetically patterned flat substrate. Combining the magnetic stray field landscape that originates from periodic magnetic stripe domains of gradually decreasing/increasing length with external magnetic field pulses, converging and diverging motion trajectories were induced for the particles. Ultimately, this led to a controlled formation and decomposition of closely packed particle clusters. We will discuss how the observed behavior is determined by the acting forces and how it is influenced by the duration of the external field pulses.
[1] Rampini *et al.* (2021), Scientific Reports, 11(1):5302.

MA 36.5 Thu 10:30 HSZ 401

Distance- and size-dependence of the interactions within highly ordered magnetic nanoparticle mesocrystals
— •Nils Neugebauer[1,2], Yi Wang[3], Matthias Elm[1,2], Xingchen Ye[3], Christian Heiliger[1,4], 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]Department of Chemistry, Indiana University, Bloomington, Indiana 47405, United States — [4]) Institute for Theoretical Physics, Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Ferromagnetic resonance (FMR) experiments in combination with micromagnetic simulations are employed to investigate and characterize dipolar interactions between magnetic nanoparticles (MNPs) within such mesocrystals. The MNPs investigated in this work consist of iron oxide (magnetite - Fe3O4) and are coated with non-magnetic polymers, forming highly ordered hexagonal monolayer crystals. The magnetic response of the regularly arranged hexagonal mesocrystals can be tuned in a controlled way by varying the thickness of the non-magnetic polymer coating of the MNPs and thus the lattice constant of the mesocrystal.

The spectral features show distinct dipolar coupling phenomena within the mesocrystal and reveal that the material parameters of the MNPs such as the magnetization and the magnetocrystalline anisotropy are reduced with respect to their bulk counterpart.

MA 36.6 Thu 10:45 HSZ 401

Monte Carlo simulation of the aggregation of confined superparamagnetic colloids
— •Javier Valenzuela[1,2], Francisco Gámez[2], and Perla Viveros-Méndez[3] — [1]Fritz Haber Institute of the Max Planck Society, Berlin, Germany — [2]Complutense University of Madrid, Madrid, Spain — [3]Autonomous University of Zacatecas, Zacatecas, Mexico

The properties of colloidal suspensions of superparamagnetic nanoparticles confined within inorganic and organic cavities have led to a num-

ber of interesting applications in areas such as nanomedicine, microfluidics, and nanorobotics. Therefore, predicting the morphology of the structures formed during the aggregation process of these particles under different scenarios is of key scientific interest.

In this work, the Monte Carlo and cluster-moving Monte Carlo methods have been employed to study the aggregated structures formed by magnetic particles confined in spherical (3D) and circular (2D) cavities. The impact of the number of particles, their initial configuration and the pair-potential model between the particles and between the particles and the cavity surface on the aggregated structure is assessed. Moreover, we present an improvement of the cluster-moving Monte Carlo method to increase the computational performance under curved confinement situations. This work provides insights that might prove useful for the development of more efficient simulation strategies that could play a crucial role in the design and prediction of new applications of this relevant type of colloidal systems.

MA 37: Magnetic Heuslers

Time: Thursday 9:30–11:00 Location: HSZ 403

MA 37.1 Thu 9:30 HSZ 403

Enhanced magnetism of antiphase boundaries in Fe_2CoAl compound — Martin Friák[1], Josef Gracias[2], Jana Pavlů[2], and •Mojmír Šob[2,1] — [1]Inst. Phys. Mat., Czech Acad. Sci., Brno, Czech Rep. — [2]Dept. Chem., Fac. Sci., Masaryk Univ., Brno, Czech Rep.

We performed a quantum mechanical examination of thermodynamic, structural, elastic, and magnetic properties of single-phase ferromagnetic Fe_2CoAl with a chemically disordered B2-type lattice with and without antiphase boundaries (APBs) with (001) crystallographic orientation. Fe_2CoAl was modeled using two different 54-atom supercells with atoms on the two B2 sublattices distributed according to the special quasi-random structure (SQS) concept. Both computational models used exhibited very similar formation energies (−0.243 and −0.244 eV/atom), B2-structure lattice parameters (2.849 and 2.850 Å), magnetic moments (1.266 and 1.274 μ_B/atom), practically identical single-crystal elastic constants (C_{11} = 245 GPa, C_{12} = 141 GPa, and C_{44} = 132 GPa) and auxetic properties (the lowest Poisson ratio close to -0.1). In contrast to these similarities, the averaged APB interface energies were observed to be 199 and 310 mJ/m^2 for the two models. The studied APBs increased the total magnetic moment by 6 and 8 % due to a volumetric increase as well as local changes in the coordination of Fe atoms (their magnetic moments are reduced for increasing number of Al neighbors but increased by the presence of Co). The APBs also enhanced the auxetic properties.

MA 37.2 Thu 9:45 HSZ 403

VTaNbAl: A new class of spin gapless semiconductor with topological non-trivial features — •Deepika Rani[1], P. C. Sreeparvathy[2], K. Gopi Suresh[2], Ratnamala Chatterjee[1], and Aftab Alam[2] — [1]Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India — [2]Department of Physics, Indian Institute of Technology Bombay, Mumbai 400076, Maharashtra, India

We report the theoretical prediction of a new class of spin gapless semiconductor (SGS) hosting topological non-trivial features along with a fully compensated ferrimagnetic state in VTaNbAl, a quaternary Heusler alloy. Unlike conventional SGS, this new class of compound acquires a unique band structure with opposite spin characters in the valance and conduction band edges making them potential candidates for spin valves and large anomalous Nernst effect. Interestingly, despite of a compensated ferrimagnetic (CF) behavior, VTaNbAl shows a reasonably large anomalous Hall effect possibly arising from the intrinsic non-vanishing Berry curvature. The CF state breaks the time-reversal symmetry and hence opens the possibility of Weyl nodes. We found four pairs of Weyl nodes located near the Fermi level leading to the non-zero Berry curvature, and hence a large anomalous Hall conductivity (~ 100 S/cm). Our experimental synthesis confirms NbVTaAl to crystallize in a cubic Heusler structure with an A2-type disorder. Magnetization measurement shows a very small saturation moment, which agrees fairly well with our theoretical findings of fully compensated ferrimagnetism in the alloy.

MA 37.3 Thu 10:00 HSZ 403

Long range ordering in NiCoMnAl magnetic shape memory thin films with martensitic intercalations — •Inga Ennen, Dario Stierl, Laila Bondzio, and Andreas Hütten — Thin Films and Physics of Nanostructures, Physics Department, Bielefeld University, 33615 Bielefeld, Germany

Magnetic shape memory Heusler alloys, like NiMnX (X=Al,Ga,Sn,In), are considered as promising materials for magnetocaloric cooling applications due to their magnetoelastic coupling near room temperature. In order to reduce the thermal hysteresis in NiCoMnAl thin films, the usage of alternating active transforming austenitic and martensitic intercalation layers are beneficial. Therefore, the stoichiometry of these two layers is chosen in such a way that their thermal hysteresis does not overlap. If the austenite active layers have a similar thickness compared to the martensite intercalations a 3D check board pattern becomes visible in HRTEM cross section images. The contrast is due to alternating martensite/austenite domains.

In this contribution we aim for an improved understanding of the 3D check board pattern formation. Therefore, the number of the alternating layers as well as the ratio between the thicknesses of the two different layers have been varied. The phase transition has been characterized by temperature dependent XRD and TEM analysis. Furthermore, freestanding Heusler films have been prepared and analyzed in comparison to the substrate-bounded systems.

MA 37.4 Thu 10:15 HSZ 403

Anomalous Hall effect in epitaxial thin films of the hexagonal Heusler MnPtGa noncollinear hard magnet — •Edouard Lesne[1], Rebeca Ibarra[1,2], Bushra Sabir[3], Bachir Ouladdiaf[4], Ketty Beauvois[4], Alexandr Sukhanov[2], Rafal Wawrzynczak[1], Walter Schnelle[1], Anton Devishvili[4], Dmytro Inosov[2], Jacob Gayles[3], Claudia Felser[1], and Anastasios Markou[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]University of South Florida, Tampa, United States of America — [4]Institut Laue-Langevin, Grenoble, France

Centrosymmetric MnPtGa Heusler films grown by magnetron sputtering on (0001)$-Al_2O_3$ crystallize with an out-of-plane c-axis crystal orientation, along which they exhibit perpendicular magnetic anisotropy below their Curie temperature (T_C = 263 K). Further, below a thermally induced spin reorientation transition at 160 K, the magnetic groundtstate, determined by single-crystal neutron diffraction, is found to be a noncollinear spin-canted state where the Mn moments tilt 20° away from the c-axis [*Appl. Phys. Lett.* 120, 172403 (2022)].

Furthermore, the anomalous Hall conductivity (AHC) of 20−60 nm thick MnPtGa epitaxial films is found to exhibit a strongly nonmonotonic behaviour as a function of longitudinal conductivity and temperature, whereby the AHC changes sign at T^* = 110 K. Our findings, supported by first-principle calculations, hint at an anomalous Hall effect of intrinsic origin driven by a momentum-space Berry curvature mechanism [*Adv. Mater. Interfaces* 9, 2201562 (2022)].

MA 37.5 Thu 10:30 HSZ 403

Effect of increasing Mn content on twin mobility in Mn-excess Ni-Mn-Ga alloys — •Martin Heczko[1], Petr Šesták[2], and Martin Zelený[1] — [1]Institute of Materials Science and Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic — [2]Institute of Physical Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic

Martensitic phases of Ni-Mn-Ga ferromagnetic shape memory alloy are considered to be useful in various advanced engineering applications due to reported giant magnetic field induced strain (MFIS). The MFIS originates in the high mobility of twin boundaries combined with large magneto-crystalline anisotropy. We calculated the generalized planar fault energy (GPFE) curves using the spin-polarized DFT method implemented in the Vienna Ab Initio Simulation Package (VASP) to reveal the effect of increasing concentration of excess Mn and its magnetic ordering on formation and propagation of twin boundaries. Effects of local arrangement of excess Mn atoms in Ga sublattice has been considered as well.

Our results show that the barriers for nucleation and grow of a twin rise with increasing content of Mn. It results in more difficult twin formation and propagation in compositions far from stoichiometry. This effect is even more enhanced if excess Mn atom in Ga sublattice is located exactly in the planar fault, and when they are ordered antiferromagnetically.

MA 37.6 Thu 10:45 HSZ 403

The impact of disorder on the 4O-martensite of Ni-Mn-Sn Heusler alloy — •Martin Friák[1], Martin Zelený[2,3], Jiří Kaštil[4], Jiří Kamarád[4], Martin Míšek[4], Zdeněk Arnold[4], Ilja Turek[1], Oldřich Schneeweiss[1], and Mojmír Šob[5,1] — [1]Institute of Physics of Materials, Czech Academy of Science, Brno, CZ — [2]Institute of Materials Science and Engineering, Faculty of Mechanical Engineering, Brno University of Technology, Brno, CZ — [3]Faculty of Mathematics and Physics, Charles University, Prague, CZ — [4]Institute of Physics, Czech Academy of Sciences, Prague, CZ — [5]Department of Chemistry, Faculty of Science, Masaryk University, Brno, CZ

We have performed a quantum-mechanical study of thermodynamic, elastic, magnetic and structural properties of four different ferrimagnetic states in $Ni_{1.9375}Mn_{1.5625}Sn_{0.5}$ martensite. They are modeled by the four-layer modulated 4O structures with Mn-excess atoms randomly distributed in Ni and Sn sublattices. The Mn atoms at the Ni sublattice turn out to play a key role in the system. A reversal of the orientation of their local magnetic moments has a huge impact on the properties of the whole system. The lowest-energy configuration exhibits anti-parallel local magnetic moments of these Mn atoms with respect to the orientation of the total magnetic moment. By testing both elasticity and phonons we conclude that the lowest-energy state is mechanically stable. Vibrational properties of individual atoms are found to be very sensitive to the chemical disorder. For details see Intermetallics 151 (2022) 107708, DOI:10.1016/j.intermet.2022.107708.

MA 38: Micro- and Nanostructured Magnetic Materials

Time: Thursday 11:30–12:45 Location: HSZ 401

MA 38.1 Thu 11:30 HSZ 401

Chemically modulated Fe-Ni cylindrical nanowires with asymmetric magnetic response — •Claudia Fernandez[1,2], Alba Berja[2,3], Lucia Aballe[4], Laura Alvaro[1], Carolina Martin[5], Michael Foerster[4], Ruy Sanz[5], Arantzazu Mascaraque[2], Lucas Perez[1,2], and Sandra Ruiz[6] — [1]IMDEA Nanoscience, 28049, Spain — [2]Materials Physics Department, UCM, 28040, Spain — [3]Institute of Ceramics and Glass (CSIC), 28040, Spain — [4]ALBA Synchrotron, 08290, Spain — [5]National Institute of Aerospace Technology, 28850, Spain — [6]MPI for Chemical Physics of Solids, 01187, Germany

The control of the magnetic domain walls (DWs) movement along cylindrical nanowires (NWs) by means of magnetic fields or electric currents is a key aspect in the design of novel spintronic devices. In recent studies, we have demonstrated that local changes in composition along the axis of Fe20Ni80 nanowires can pin the DWs and that the DWs can be moved under the application of magnetic field. Expanding this concept, in this work we propose a gradual change in Fe/Ni ratio along the axial direction of the nanowires in order to create an asymmetric energy landscape with the aim to induce asymmetric domain wall motion. Combining X-ray imaging techniques (XAS and XMCD) we have correlated the chemical structure of single nanowires with their magnetic configuration. In First Order Reversal Curves (FORC) diagrams we have observed that an asymmetry arises evidencing the emerging of asymmetrical magnetization processes in the array.

MA 38.2 Thu 11:45 HSZ 401

Chirality coupling in curvilinear nanoarchitectures — •Oleksii M. Volkov[1], Daniel Wolf[2], Oleksandr V. Pylypovskyi[1,3], Attila Kákay[1], Denis D. Sheka[4], Bernd Büchner[2,5], Jürgen Fassbender[1], Axel Lubk[2,5], and Denys Makarov[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, Dresden, Germany — [2]Institute for Solid State Research, IFW Dresdenm Dresden, Germany — [3]Kyiv Academic University, Kyiv, Ukraine — [4]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [5]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany

Symmetry effects are key building blocks of condensed matter physics as they define not only interactions but also resulting responses for the intrinsic order parameter. Namely, in magnetism geometric curvature governs the appearance of chiral and anisotropic responses [1], that introduce a new toolbox to create artificial chiral nanostructures from achiral magnetic materials [2,3]. Here, we demonstrate both theoretically and experimentally the existence of non-local chiral effects in geometrically curved asymmetric permalloy caps with the vortex texture. We find that the equilibrium vortex core obtain bend and curling deformation, that are dependent on the geometric symmetries and magnetic texture parameters.

[1] D. D. Sheka et al., Comm. Phys. **3**, 128 (2020).
[2] O. M. Volkov et al., Phys. Rev. Lett, **123**, 077201 (2019).
[3] D. Makarov et al., Adv. Mater. **34**, 2101758 (2022).

MA 38.3 Thu 12:00 HSZ 401

Towards magnetic MXenes via thermal activation of $Ti_3C_2T_x$ and Fe intercalation — •Tim Salzmann[1], Hanna Pazniak[2], Ivan Tarasov[1], Michael Farle[1], and Ulf Wiedwald[1] — [1]University of Duisburg-Essen and Center for Nanointegration Duisburg-Essen, Germany — [2]Université Grenoble Alpes, CNRS, Grenoble INP, LMGP, France

MXenes are 2D materials obtained from a MAX phase precursor. The $Ti_3C_2T_x$ MXene surface is stabilized by a T_x termination in the form of $-F, -Cl, =-O, -OH$ [1]. $Ti_3C_2T_x$ MXenes deposited on $Si(100)/SiO_2$ are annealed at T=1023 K in ultrahigh vacuum removing −F, −Cl and −OH confirmed by in situ mass spectroscopy, and Auger electron spectroscopy (AES). Additionally, we find a reduction of interplanar spacing between MXene sheets ($d_{ini} - d_{ann} = 0.30 \pm 0.04$ nm) by X-ray diffraction (XRD). Subsequently, a 6 nm thick Fe film is deposited and annealed between 550 K and 1000 K. AES displays a linear decrease of the Fe concentration at the surface from 85% to 15% as a function of annealing temperature. The intercalation of Fe is confirmed by XRD measurements showing an increase of the interplanar spacing between MXene sheets ($d_{int} - d_{ann} = 0.16 \pm 0.02$ nm). In plane vibrating sample magnetometry reveals a saturation magnetization of 1728 ± 150 kA/m for the 6 nm Fe film on top of MXenes confirming bulk metallic Fe. After annealing up to 800 K, the magnetization decreases to 660 ± 80 kA/m and the Curie temperature to 485 K. Funded by DFG-Project-ID 405553726-TRR 270.

[1] James L. Hart et al., ACS Nanoscience Au 2022 2, 433-439

MA 38.4 Thu 12:15 HSZ 401

Magneto-optical investigation of 3D-curved toroidal ferromagnetic thin films — •Christian Janzen[1], Sapida Akhundzada[1], Bhavadip Bharatbhai Rakholiya[1], Arne Vereijken[1], Claudio Beck[1], Piotr Kuświk[2], Michał Matczak[2,3], Michael Vogel[1,4], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Germany — [2]Institute of Molecular Physics, Polish Academy of Science, Poznań, Poland — [3]Faculty of Physics, University of Białystok, Poland — [4]Department of Materials Science, University of Kiel, Germany

Magnetic thin films, typically examined as flat two-dimensional systems, may be extended to the third dimension by deposition of the magnetic material on curved substrates. To experimentally investigate physical effects induced by the geometry and curvature of a thin film magnet, micron-sized curved structures with minimal surface roughness were prepared by optimized two-photon polymerization lithography processes. These structures are deliberately placed with well-defined lateral as well as axial spacing, leading to periodic arrays where, e.g., the influence of varying magnetostatic interactions between the individual objects can be investigated. In this work, the magnetization reversal of periodic arrays of hemispherical tori with varying lattice geometry of the periodic array will be investigated by magneto-optical Kerr magnetometry/microscopy. The experimental results are further compared with micromagnetic simulations.

MA 38.5 Thu 12:30 HSZ 401

Sprayed Nanometer-Thick Hard Magnetic Coatings with

Strong Perpendicular Anisotropy for Data-Storage Applications — •Andrei Chumakov[1], Calvin J. Brett[1,2], Korneliya Gordeyeva[2], Dirk Menzel[3], Lewis O. O. Akinsinde[4], Marc Gensch[1], Matthias Schwartzkopf[1], Wei Cao[5], Shanshan Yin[5], Manuel A. Reus[5], Michael A. Rübhausen[4], Peter Müller-Buschbaum[5,6], Daniel Söderberg[2], and Stephan V. Roth[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]DE 118714904 — [3]Notkestraße 85, DESY — [4]Universität Hamburg, Hamburg, Germany — [5]Technische Universität München, Garching, Germany — [6]Heinz Maier-Leibnitz Zentrum, Garching, Germany

We present a study of a facile technology for establishing mono- and multi-layer surfaces from various single-domain flat magnetic nanoparticles that exhibit a strong perpendicular-oriented magnetic moment on solid and flexible substrates. Surfactant-free, hard ferromagnetic and single-domain anisotropic strontium hexaferrite nanoparticles with perpendicular magnetic moment orientation and two different aspect ratios are self-ordered into magnetic thin nanofilms exploiting the templating effect of cellulose nanofibrils and magnetic fields. Uniform magnetic coatings obtained by scalable layer-by-layer spray deposition from a monolayer coverage up to thicknesses of a few tens of nanometers show preferred in-plane orientation of the hard-magnetic nanoparticles.

MA 39: Weyl Semimetals

Time: Thursday 11:30–12:45 Location: HSZ 403

MA 39.1 Thu 11:30 HSZ 403

Topological spin textures stabilised by Weyl fermions — •Juba Bouaziz[1], Gustav Bihlmayer[1], Julie B. Staunton[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut Forschungszentrum Jülich — [2]The university of Warwick

Rare-earth intermetallic (REI) constitute a playground for the realization of topological spin textures relying on Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions between the localized 4f-moments [1]. In non-centrosymmetric REI, namely REAlGe (Si), the breaking of inversion symmetry generates Weyl nodes which display interesting topological properties. The Weyl fermions mediate highly anisotropic RKKY interactions leading to the emergence of Kitaev (KT) and Dzyloshinksii-Moriya (DM) interactions. The incommensurate magnetic order present in these systems can be tied to the nesting of topological Fermi pockets [2]. We perform a systematic first-principles analysis in the framework of the DFT+U for REAlGe (RE=Ce-Gd) and investigate the contributions of the different exchange interactions (isotropic, DM, and KT) to incommensurate order. The local crystal field coefficients are computed from first-principles as well and are used to evaluate the magneto-crystalline anisotropy. Finally, we employ atomistic spin-dynamic simulations and identify the magnetic phases that are stabilized in presence of an external magnetic field. Our analysis aims at drawing a direct connection between the topology of the electronic band structure and the topology of the spin structures in real space. [1] J. Bouaziz et al. PRL 128, 157206 (2022) [2] J. Gaudet et al. Nat Mat 20, 1650 (2021)

MA 39.2 Thu 11:45 HSZ 403

Pressure induced ferromagnetic collapse and valence instability in EuB_6 — •Leonardo Kutelak[1], Raimunda Sereika[2], Gilberto Fabbris[3], Gustavo Lombardi[1], Daniel Haskel[3], Narcizo Souza Neto[1], Priscila Rosa[4], Wenli Bi[2], and Ricardo Reis[1] — [1]Brazilian Synchrotron Light Laboratory (LNLS), Brazilian Center for Research in Energy and Materials (CNPEM),Campinas, Sao Paulo, Brazil — [2]University of Alabama at Birmingham - Birmingham, AL 87545, USA — [3]Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois 60439, USA — [4]Los Alamos National Laboratory - Los Alamos, NM 87545, USA

The only ferromagnetic rare earth hexaboride, EuB_6, presents previously reported interesting behavior such as a two-step magnetic transition below 15 K[1] and magnetic polarons up to 40 K[!]. Most recently, it was proposed that EuB_6 may host non-trivial electronic behavior near Fermi surface presenting either Weyl Points or nodal lines depending upon magnetization ordering and direction. We show evidences for EuB_6 ferromagnetic collapse above 20 GPa with mean valency increase by X-ray spectroscopy techniques. No signs for structural phase transitions were observed in high pressure X-ray diffraction. This opens up new possibilities for fine tuning topological properties utilizing pressure in rare earth hexaborides.

[1]Süllow, Structure, et al. Physical Review B 57.10 (1998): 5860. [2]Pohlit, Merlin, et al Physical review letters 120.25 (2018): 257201. [3]Nie, Simin, et al. Physical Review Letters 124.7 (2020): 076403.

MA 39.3 Thu 12:00 HSZ 403

High pressure studies of the topological Hall effect on CeAlGe — •Mario M. Piva[1], Jean C. Souza[2], Gustavo A. Lombardi[3,1], Kevin R. Pakuszewski[4], Cris Adriano[4], Pascoal G. Pagliuso[4,5], and Michael Nicklas[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]The Weizmann Institute of Science, Rehovot, Israel — [3]Brazilian Synchrotron Light Laboratory (LNLS), Campinas, Brazil — [4]"Gleb Wataghin" Institute of Physics, Campinas, Brazil — [5]Los Alamos National Laboratory, Los Alamos, USA

The Weyl semimetal CeAlGe is an excellent playground to investigate non-trivial topologies in real and momentum space due to the presence of a topological magnetic phase [1]. Our findings show that, the THE in CeAlGe is sensitive to slight stoichiometric variations, similar to its magnetism [2]. The observed change of a single THE region to two distinct regions upon application of external pressure is in agreement with previous reports [3]. Remarkably, we find that application of high pressures leads to the appearance of a THE even in samples where it was absent at ambient pressures.

This project has received funding from the European Unions Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101019024.

[1] P. Puphal, *et al.*, Phys. Rev. Lett. **124** 017202 (2020); [2] P. Puphal, *et al.*, Phys. Rev. Mat. **3** 024204 (2019); [3] X. He, *et al.*, arXiv:2207.08442.

MA 39.4 Thu 12:15 HSZ 403

Magnetic and Electronic Structure of $Eu(Cd,Zn)_2P_2$ — •Sarah Krebber[1], Kristin Kliemt[1], Marvin Kopp[1], Charu Garg[1], Jens Müller[1], Kurt Kummer[2], Denis Vyalikh[3], and Cornelius Krellner[1] — [1]Institute of Physics, Goethe-University, Frankfurt (Main), Germany — [2]ESRF, Grenoble, France — [3]DIPC, Donostia-San Sebastián, Spain

The interplay of topology and magnetism has been of great interest in the last few years. The coexistence of both phenomena can be realized in europium based compounds with the 122 stoichiometry and a trigonal crystal structure ($P\bar{3}m1$). Recently, a spin fluctuation induced Weyl semimetal state in the paramagnetic phase of $EuCd_2As_2$ [1,2] and its tunability by pressure [3] was discovered. Furthermore, $EuCd_2P_2$ has been explored due to its colossal magnetoresistance [4], where the origin of the effect was explained by the formation of ferromagnetic clusters [5].
With the aim of studying the magnetic and electronic properties of $EuCd_2P_2$ compound in detail and finding similar effects in $EuZn_2P_2$ both systems were studied. Here, we present the successful crystal growth and characterization via magnetization, electrical transport, heat capacity and spectroscopy.

[1] Ma et al., Science Adv. 5, eaaw4718 (2019). [2] Jo et al., Phys. Rev. B 101, 140402(R) (2020). [3] Gati et al., Phys. Rev. B 104, 155124 (2021). [4] Wang et al., Adv.Mater., 33, 2005755 (2021). [5] Sunko et al., arXiv:2208.05499, (2022).

MA 39.5 Thu 12:30 HSZ 403

Novel thermo-electric transport channel in the conformal limit of tilted Weyl semimetals — Thorvald Ballestad[1], Alberto Cortijo[2], María Vozmediano[3], and •Alireza Qaiumzadeh[1] — [1]Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway — [2]Universidad Autonoma de Madrid, Madrid, Spain — [3]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

Recently, a new contribution to the Nernst current was proposed in 3D Dirac and Weyl semimetals, originated from quantum conformal anomaly [1,2]. In the present study, we analyze the effect of the tilt on the transverse thermo-electric coefficient of Weyl semimetals in the conformal limit, i.e., zero temperature and zero chemical potential. Using the Kubo formalism, we find a non-monotonic behavior of the thermoelectric conductivity as a function of the tilt perpendicular to the magnetic field, and a linear behavior when the tilt is aligned to the magnetic field. An "axial Nernst" current is generated in inversion symmetric materials when the tilt vector has a projection in the direction of the magnetic field. This analysis will help in the design and interpretation of thermo-electric transport experiments in recently discovered topological quantum materials [3].

[1] M. N. Chernodub et al, Phys. Rev. Lett. 120, 206601 (2018). [2] V. Arjona et al, Phys. Rev. B 99, 235123 (2019). [3] T. M Ballestad, A. Cortijo, M. A. H. Vozmediano, A. Qaiumzadeh, arXiv:2209.14331 (2022).

MA 40: Poster Magnetism II

Magnetic Domain Walls (non-skyrmionic) (MA 40.1-40.5), Ultrafast Magnetization Effects (MA 40.6-40.12), Magnetic Relaxation and Gilbert Damping (MA 40.13), Magnetic Semiconductors (MA 40.14-40.15), Complex magnetic oxides (MA 40.16-40.20), Frustrated Magnets (MA 40.21-40.27), Thin Films: Magnetic Coupling Phenomena / Exchange Bias (MA 40.28-40.32), Thin Films: Magnetic Anisotropy (MA 40.33-40.34), Magnetic Instrumentation and Characterization (MA 40.35-40.42), Magnetic Particles / Clusters (MA 40.43-40.44), Magnetic Information Technology, Recording, Sensing (MA 40.45-40.48), Micro- and Nanostructured Magnetic Materials (MA 40.49-40.50), Multiferroics and Magnetoelectric Coupling (MA 40.51), Surface Magnetism (MA 40.52-40.55), Cooperative Phenomena: Spin Structures and Magnetic Phase Transitions (MA 40.56-40.58), Topological Insulators (MA 40.59), Topological Insulators (MA 40.60-40.61), Disordered Magnetic Materials (MA 40.62), Focus Session: Altermagnetism: Transport, Optics, Excitations (MA 40.63-40.64), Spin-Phonon Coupling (MA 40.65-40.66)

Time: Thursday 14:00–16:00 Location: P2/EG

MA 40.1 Thu 14:00 P2/EG

The spectrum of localized excitations of spin nanoclusters and their stability in a magnetic field — •Oksana Charkina[1,2], Mikhail Bogdan[2], and Igor Poltavsky[1] — [1]University of Luxembourg, L-1511 Luxembourg City, Luxembourg — [2]B. Verkin ILTPE of NASU, Kharkiv, 61103, Ukraine

Engineering novel materials with predefined spectral and dynamical properties from recently synthesized giant magnetic molecules, permitting well-controlled exchange interaction, is essential for creating memory elements in modern computer technologies. To provide the necessary theoretical basis, we studied the structure and internal dynamics of spin nanoclusters limited by discrete domain walls in ferromagnetic chains placed in a magnetic field. The spin nanoclusters and their spectra of localized excitations are described analytically within the framework of the discrete Takeno-Homma equation [1], which fully accounts for the exchange interaction between spins. Explicit expressions for the internal mode oscillations were found, and the frequency dependences on the parameters of the exchange and the magnetic field were calculated. In addition, a stripe-like stability diagram and the Peierls energy barrier for the noncollinear discrete domain walls were established. We found that the magnetic field can effectively control the localization of information and energy on spin clusters. Our results can be used in developing spin-cluster resonance methods for investigating magneto-optical properties of a new class of low-dimensional metamaterials.

1. Takeno S. and Homma S., J.Phys.Soc.Jpn. 55, 2547 (1986).

MA 40.2 Thu 14:00 P2/EG

Curvature-induced effects in dynamics of domain walls in chiral biaxail nanotubes — •Kostiantyn V. Yershov[1,2] and Denis D. Sheka[3] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine — [3]Taras Shevchenko National University of Kyiv, Ukraine

Tubular geometry is paradigmatic example for studying numerous chiral effect. The competition between intrinsic Dzyaloshinskii–Moriya interactions (DMI) and geometry-governed DMI become the source of emergent magnetochiral effects leading to essential modification of critical DMI strength, appearance of new type of domain walls (DWs) [1]. Here, we present a detailed study of static and dynamic properties of DWs in chiral biaxial nanotubes. The easy and hard axises are oriented in azimuthal and radial directions, respectively. (i) First, we considered the static properties of magnetic DWs in nanotubes with different symmetries of DMI. We found that the presence the chiral interaction results in the deformation of the DW profile: for interfacial type of DMI the DW phase has an asymmetrical slope; for bulk type of DMI the DW phase has a linear shift. In both cases deformation is proportional to the strength of DMI (ii) Dynamics of DWs with interfacial DMI results in the linear shift of the Walker field. While, for the case of the a bulk type of DMI we show that the presence of chiral interation results in the emergent magnetochiral effect, i.e. the polarity-helicity coupling. [1] K. Yershov et al, SciPost Phys. **9** (2020), 043.

MA 40.3 Thu 14:00 P2/EG

Dynamics of bound domain walls in the 3D magnetic double helix — •Imelda Pamela Morales Fernandez[1], Sandra Ruiz-Gómez[1], Aurelio Hierro-Rodríguez[2], Simone FInizio[3], Sebastian Wintz[4], Näemi Leo[5], Markus König[1], Claas Abert[6], Dieter Süss[6], Amalio Fernandez-Pacheco[5], and Claire Donnelly[1] — [1]Max Planck Institute for Chemical Physics of Solids — [2]University of Oviedo — [3]Paul Scherrer Institute — [4]Helmholtz Center Berlin — [5]Institute of Nanoscience and Materials of Aragon — [6]University of Vienna

Magnetic domain walls are stable magnetic textures that promise exciting opportunities for advances in technological applications in a wide range of fields. In contrast with their 2D counterparts, DWs in 3D nanosystems can exhibit more complex configurations, with prospects for exotic dynamic behavior. In this framework, double helix nanostructures combine geometrical effects of curvature and chirality with intrinsic exchange and magnetostatic coupling giving rise to a new state consisting of a highly coupled pair of domain walls (head-to-head and tail-to-tail) within the neighboring helices. The cobalt double helix fabricated by the FEBID technique is an ideal platform to experimentally investigate the static and dynamic properties of the coupled domain walls: it is a trustworthy platform to induce the vortex and antivortex textures in the magnetic field of the coupled domain wall state and on the other hand it is a promising system to achieve robust DW motion and synchronous dynamics with ultra-high DW mobilities overcoming the Walker breakdown.

MA 40.4 Thu 14:00 P2/EG

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]TWIST group, University of Duisburg-Essen, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [3]Politecnico di 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] Stuart S. P. Parkin and et. al. Nat.Nanotechnol. 10 (2015)
[2] M. Sitte et al. Phys. Rev. B 94, 064422 (2016)

MA 40.5 Thu 14:00 P2/EG

Imaging the antiferromagnetic domain structure of α-Fe2O3 and its magnetic field dependence — •Julian Skolaut[1], Kai Litzius[2,3], Markus Weigand[4], Olena Gomonay[1], Elizaveta Tremsina[5], Sebastian Wintz[3,4], Norman Birge[6], Geoffrey Beach[5], and Angela Wittmann[1] — [1]Johannes Gutenberg University, Mainz — [2]University Augsburg — [3]MPI Intelligent Systems, Stuttgart — [4]HZB, Berlin — [5]MIT, Cambridge, USA — [6]Michigan State University, East Lansing, USA

In recent years, antiferromagnets have gained increasing attention for spintronics applications due to their favorable properties such as vanishing stray fields. Moreover, the domain structure formation mechanism is different from ferromagnets. Here, we study the canted antiferromagnet hematite α-Fe2O3. The canting of the spins yields a small in-plane magnetization, lifting the degeneracy of the Néel vector orientation w.r.t. an external magnetic field. Our measurements investigate the magnetic domain structure of hematite, specifically the movement of domain walls by application of an external magnetic field. For this, we have imaged the domain structure of α-Fe2O3 by taking x-ray magnetic linear dichroism (XMLD) contrast images of the domain structure of α-Fe2O3 by total electron yield using a scanning x-ray microscope. This method allows imaging of the domain structure within an applied magnetic field and studying the domain structure, as well as the displacement of domain walls as a function of the magnetic field. A thorough analysis of the changes in domain structure will elucidate the underlying mechanisms for the formation of magnetic domains.

MA 40.6 Thu 14:00 P2/EG

Tuning all-optical magnetization switching efficiency by laser pulse wavelength variation — •Marcel Kohlmann[1], Lucas Vollroth[1], Kristýna Hovovřáková[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

The relevance of heat-assisted magnetic recording (HAMR) motivates ongoing research and development in magnetization manipulation. We study all-optical helicity-dependent switching (AOHDS) of FePt granular media as a viable alternative method for magnetic writing of HAMR media. The interplay of magnetic dichroism and inverse Faraday effect is currently understood as driving process behind the magnetization reversal. Ab-initio calculations of magnetic dichroism and inverse Faraday effect for the switching rates of single FePt nano particles provided us with a stochastic model for the switching process. We now present data for the wavelength dependent efficiency of the writing process from 800 nm - 1550 nm. We greatly acknowledge the DFG funding within the project "Fundamental aspects of all-optical single pulse switching in nanometer-sized magnetic storage media.

MA 40.7 Thu 14:00 P2/EG

Coherent excitation of spin waves in thin nickel films during ultrafast remagnetization — •Akira Lentfert[1], Anulekha De[1], Laura Scheuer[1], Benjamin Stadtmüller[1,2], Burkard Hillebrands[1], Georg von Freymann[1,3], Martin Aeschlimann[1], and Philipp Pirro[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, Germany

The remagnetization process after ultrafast demagnetization can be described by relaxation mechanisms between the spin, electron, and lattice reservoirs. The angular momentum transfer between them is the subject of current research, especially the role of collective spin excitations remains comparably unexplored. In our work, we study the pump fluence-dependent excitation of coherent spin waves in thin nickel films. Using the all-optical, time-resolved magneto-optical Kerr-effect (tr-MOKE) technique, we investigate the role of coherent spin waves after the laser-induced demagnetization. We show that the largest spin-wave amplitude is observed close to the fully demagnetized state. Furthermore, the coherence of the system appears to be conserved during de- and remagnetization, even when the magnetization is quenched by up to 90%. Interestingly, the phase of the coherent oscillations relative to the initial laser pulse is strongly dependent on the laser fluence which indicates that the coherent precession is influenced by the demagnetization itself. This research was supported by the DFG through No. TRR 173-268565370 (project B11).

MA 40.8 Thu 14:00 P2/EG

Laser-induced ultrafast 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 Bärbel Rethfeld[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU, Kaiserslautern, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany

Studying the optically induced magnetization dynamics of heterostructures has provided clear insights into the particle and energy transport effects on ultrafast timescales. This understanding leads to new concepts to control the magnetization dynamics by tuning the wavelength of optical excitation [1, 2, 3].

In this contribution we demonstrate how the magnetization dynamics of Ni|Au heterostructures can also be controlled by the thickness of the non-magnetic gold layer. Our conclusions are based on an extended temperature-based μT-model which includes the thickness-dependent absorption profile. We find that thin gold films slow down the demagnetization process of nickel while the demagnetization times decrease again for larger gold film thicknesses. Furthermore we consider transport effects within the gold layer and demonstrate the dependence of the induced spin polarization into the substrate on the considered depth in the substrate.

[1] V. Cardin *et al.*, Phys. Rev. B 101, 054430 (2020)
[2] M. Stiehl *et al.*, Appl. Phys. Lett. 120, 062410 (2022)
[3] C. Seibel *et al*, Phys. Rev. B 106, L140405 (2022)

MA 40.9 Thu 14:00 P2/EG

Optical manipulation of magnetic order parameter in magentic insulators by ultrashort laser pulses — •Paul Herrgen[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

Magnetic insulators are highly intriging materials for high performance and sustainable magnetic storage technology. However, the existance of a band gap of several eV makes it rather challenging to optically manipulate these materials on an ultrafast, fs timescale.
Here, we used strong fs laser pulses with high photon energies to optically overcome this bandgap. Using a second ultrashort laser pulse, we were able to measure the dynamics of the magnetic order parameter of this insulator in a time-resolved manner. We find that the optical excitation leads to a fast reduction of the magnetic order on a sub-picosecond time scale. In addition, the remagnetization process takes more than 100ps to fully return to the initial magnetic ground state.

MA 40.10 Thu 14:00 P2/EG

Laser-induced metamagnetic phase transition of FeRh studied by combined UXRD and MOKE experiments — •Maximilian Mattern[1], Jasmin Jarecki[1], Vojtech Uhlir[2], Jon Ander Arregi[2], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Germany — [2]CEITEC BUT, Brno University of Technology, Czech Republic — [3]Helmholtz-Zentrum Berlin, Germany

We use time-resolved x-ray diffraction (UXRD) and the time-resolved polar magneto-optical Kerr effect (MOKE) to study the laser-induced metamagnetic phase transition in FeRh. The first-order phase transition from an antiferromagnetic (AFM) to a ferromagnetic (FM) phase is accompanied by a gigantic expansion ($\approx$ 0.6%) of the unit cell. While UXRD access the transient FM volume fraction independent of the orientation of the magnetic moment probing the enhanced lattice constant, MOKE is sensitive on the orientation of the magnetization probing the net out-of-plane magnetization.

Our combined UXRD and MOKE experiments access the nucleation, growth and coalescence of the arising FM domains and disentangle their in- and out-of-plane expansion by comparing two samples, with a thickness below and above the optical penetration depth. The thin FeRh film displays a fluence-independent rise time of the FM phase of 8 ps and a much slower rise of the net magnetization within 150 ps starting 10 ps after excitation. For the inhomogeneously excited film, we observe a strong fluence dependence of these rise times originating from an out-of-plane growth of the FM domains by heat transport.

MA 40.11 Thu 14:00 P2/EG

Consequences of Orbital Angular Momentum of Light for Electronic Dynamics — •Marvin Goronczy and Hans Christian Schneider — Physics Department, RPTU Kaiserslautern, 67653 Kaiserslautern

Recent experiments show that the orbital angular momentum (OAM) of laser pulses affects the demagnetization dynamics in ferromagnets by slowing it down or speeding it up depending on the direction of the orbital angular momentum. [1] Motivated by these experiments, we consider here the basic problem of the interaction of OAM-light with electrons in a generic band structure in order to study the effect of OAM-light on the electronic system, without attempting to include-magnetization dynamics yet. We derive the dynamical equations for the reduced electronic density matrix and its Wigner transform. We discuss the role played by different contributions, such as multipole transitions and the inhomogeneities introduced by the beam profile. Finally, we compare our results with earlier approaches to this problem.[2]

[1] E. Prinz, B. Stadtmüller, M. Aeschlimann, arXiv.2206.07502 [2] G. F. Quinteiro, P. I. Tamborenea, EPL 85/47001

MA 40.12 Thu 14:00 P2/EG

Magnetization dynamics in magnetic trilayers with a wedged antiferromagnetic spacer layer at ultrafast timescales — •Jendrik Gördes[1], Ivar Kumberg[1], Chowdhury Awsaf[1], Rahil Hosseinifar[1], Marcel Walter[1], Tauqir Shinwari[1], Sangeeta Thakur[1], Christian Schüssler-Langeheine[2], Niko Pontius[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin

We studied the time-resolved magnetization dynamics of an epitaxially grown heterostructure comprised of an antiferromagnetic (AFM) Mn wedge sandwiched between two ferromagnetic (FM) Co layers on Cu(001). The two FM layers were coupled indirectly by the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction and directly exchange coupled through the AFM spin structure, leading to parallel or antiparallel alignment of the FM layers, depending on the Mn thickness [1]. Deposition of Mn in a wedge allowed for access to different coupling regimes on the same sample. Magnetization dynamics were observed after excitation with 800 nm laser pulses by X-ray magnetic circular dichroism (XMCD) in resonant soft X-ray reflectivity. We point out the effect an antiferromagnetic spacer layer has on the magnetization dynamics of the FM layers.

[1] Bin Zhang et al., J. Appl. Phys. 115, 233915 (2014)

MA 40.13 Thu 14:00 P2/EG

Anomalous relaxation dynamics of different types of impurity models — •Michael Elbracht and Michael Potthoff — I. Institute of Theoretical Physics, University of Hamburg, Germany

The real-time relaxation dynamics of different types of one-dimensional lattice models with two additional impurities is investigated numerically. We study purely classical, purely quantum mechanical as well as semiclassical systems: (i) a model with two classical spins exchanged coupled to the classical Heisenberg model, (ii) two classical spins exchanged coupled to a tight-binding model of independent electrons, and (iii) a model with the spins replaced by two additional orbitals locally hybridizing with the tight-binding chain.

After an initial local excitation of the impurities, we trace the real-time dynamics by solving the respective fundamental equations of motion. Depending on the exact position of the impurities, the system does or does not fully relax to its local ground state. In all cases, one observes for an even distance between the impurities and after a prerelaxation to a low-energy state, that the system is trapped in a stationary oscillatory mode. Various mechanisms for this incomplete relaxation are considered, including the dynamical emergence of conserved local quantities.

MA 40.14 Thu 14:00 P2/EG

Spin reduction in the covalent chain antiferromagnets $RbFeSe_2$ and $KFeS_2$ — •Z. Seidov[1], H.-A. Krug von Nidda[1], A. Kiiamov[2], M. Kuznetsov[2], V. Tsurkan[2,3], I. Filippova[3], D. Croitori[3], F. Mayr[1], S. Widmann[1], F. Vagizov[2], D. Tayurskii[2], and L. Tagirov[2] — [1]EPV, EKM, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Kazan, Russia — [3]Institute of Applied Physics, MD-20208 Chisinau, Moldova

SQUID susceptibility, Mössbauer and specific-heat measurements show that $RbFeSe_2$ and $KFeS_2$ exhibit antiferromagnetic order below $T_N =$ 248 K and $T_N = 251$ K, respectively. The magnetic specific heat and the spin state of the Fe^{3+} ions in the compounds have been analyzed. Phonon dispersion and phonon density of states (PDOS), were evaluated from first-principles calculations. Analysis of our Mössbauer data, utilizing the calculated Fe PDOS, as well as our optical absorption measurements have shown full agreement with the location of the high-frequency optical-type lattice vibrations within the FeX_4 (X = S, Se) tetrahedra. The phonon contribution to the heat capacity has been calculated from the PDOS and subtracted from the experimental data to extract the magnetic specific heat of the quasi 1D antiferromagnetically correlated Fe^{3+} ion chains. The corresponding magnetic entropy suggests a reduced spin value for the Fe^{3+} ions in both compounds, which seems to be close to an intermediate spin state $S = 3/2$ in $RbFeSe_2$ and to a low-spin state $S = 1/2$ in $KFeS_2$.

MA 40.15 Thu 14:00 P2/EG

Growth optimization and magnetotransport properties of ferromagnetic gadolinium nitride (GdN) thin films — •Raphael Hoepfl[1,2], Manuel Müller[1,2], Johannes Weber[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]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Ferromagnetic (FM) semiconductors are of great interest for spintronic devices. Gadolinium nitride (GdN) is one candidate for a FM semiconductor with a Curie temperature T_C=65-70 K [1]. By performing SQUID magnetometry and magnetotransport experiments in a cryogenic environment, we investigate the static magnetic and magnetoresistive properties of GdN thin film heterostructures. Tantalum nitride (TaN)/GdN/TaN trilayers are grown on the thermal oxide of Si substrates using DC magnetron sputtering, where the TaN is used as a electrically conductive seed and top layer. We study the impact of the various deposition parameters, such as deposition pressure, substrate temperature, growth rate and reactive N_2 gas flow on the static magnetic properties of GdN such as T_C and saturation magnetization M_s. For GdN layer stacks grown with our optimized recipe, we perform magnetotransport experiments and identify the origin of magnetoresistance in our heterostructures.

[1] W. B. Mi *et al.*, Appl. Phys. Lett. **102**, 222411 (2013).

MA 40.16 Thu 14:00 P2/EG

Tuning the physical properties of La0.7Sr0.3MnO3-δ via oxygen off-stoichiometry using thermal annealing — •chenyang yin[1], lei cao[1], suqin he[2], tomas duchon[3], yunxia zhou[4], oleg petracic[1], and thomas brückel[1] — [1]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Peter Grünberg Institut (PGI-7), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Peter Grünberg Institut (PGI-6), JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [4]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

The oxygen off-stoichiometry in La0.7Sr0.3MnO3-δ (LSMO) thin films on SrTiO3 (STO) substrates has been investigated employing Al-assisted vacuum annealing. The gradual deoxygenation during annealing induces a topotactic phase transition from the as-prepared Perovskite (PV, ABO3) phase to a layered oxygen-vacancy-ordered Brownmillerite (BM, ABO2.5) phase. The structural change is monitored by XRD. A metal-to-insulator and simultaneously a ferromagnetic (FM)-to-antiferromagnetic (AF) transition is found. The variation of the manganese oxidation state is characterized using XAS. The BM phase shows in magnetization vs. temperature curves a peculiar peak above room temperature which cannot be explained within the usual AF ordering at low temperatures. Moreover, to elucidate the role of the strain to the substrate, bulk-like LSMO powder samples were prepared and annealed at similar conditions as the film samples. Also here the PV-BM phase transition is achieved.

MA 40.17 Thu 14:00 P2/EG

Growth and characterization of $Ca_xSr_{1-x}RuO_3$ ($x = 0, 0.3, 0.5, 0.7$) and $Sr_4Ru_3O_{10}$ single crystals — •Zahrasadat Ghazinezhad[1], Akshay Tewari[1], Agustinus Agung Nugroho[2], Kevin Jenni[1], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany — [2]Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesha 10, Bandung 40132, Indonesia

The Ruddlesden-Popper (RP) series of strontium ruthenates $Sr_{n+1}Ru_nO_{3n+1}$ manifests an interesting variety of phenomena. Here we focus on the crystal growth and on the detailed characterization of the ferromagnetic $SrRuO_3$ (n=∞, 1-1-3) and $Sr_4Ru_3O_{10}$ (n=3, 4-3-10) systems. A peculiar property of the mixed 1-1-3 materials $Ca_xSr_{1-x}RuO_3$ with $x = 0, 0.3, 0.5, 0.7$ concerns the tuning of electronic and magnetic features by substitution of smaller Ca^{2+} ions into the Sr^{2+} sites while not changing the electronic configuration [1].The triple-layer ruthenate compound $Sr_4Ru_3O_{10}$ exhibits a ferromagnetic transition at $T_C = 105K$ followed by an additional magnetic transition at $T_M = 50K$ which remains matter of controversy. This layered material also shows strong anisotropy concerning the application of magnetic fields [2]. Large single-crystals of $Sr_4Ru_3O_{10}$ could be grown by the floating-zone technique and were characterized by structural and magnetization measurements.

[1] K. Yoshimura,et al. Phys. Rev. Lett. **83**, 4397 (1999).
[2] M. Zhu, et al. Scientific reports **8**, 1 (2018).

MA 40.18 Thu 14:00 P2/EG

Analysis of Exchange Bias training effect in Exchange coupled LaFeO3 /NiO nanocomposite — •Priyanka Sharma[1] and Ratnamala Chatterjee[2] — [1]Indian Institute of Technology Delhi, New Delhi 110016, India — [2]Indian Institute of Technology Delhi, New Delhi 110016, India

Existence of exchange bias (EB) resulting from antiferromagnetic/ferromagnetic interface is well known in the literature. EB phenomenon is characterized by the horizontal shift of the magnetic hysteresis loop as the system is cooled through Neel's temperature in presence of an external magnetic field. EB is the backbone of designing magnetic storage devices and is among the modern approaches to spintronics. One of the interesting characteristics of EB is the training effect [1]. In this work, we investigate the EB training effect (TE) in LaFeO3/NiO nanocomposite synthesized by a chemical route. The consecutive measurement of field cooled (60 kOe) magnetic hysteresis loops at 5 K show that the exchange bias field (HE) decreases with the increasing number of cycles of M-H loops (n) confirming the presence of the TE effect in our sample. The experimentally observed trend between HE and n was fitted using the power law and Binek's recursive relation. From the Binek's recursive relation, the obtained value of HE infinity (EB field in the limit of infinite loops) and γ (sample dependent constant) is 1118 Oe & 6.9X10^(-7) (Oe)-2, respectively. Both, the power law and Binek's recursive relation points coincide well with the experimental observations.

[1] C. Binek, Physical Review B 70 (1), 014421 (2004).

MA 40.19 Thu 14:00 P2/EG

Impact of Currents on SDW Order in Sr_2RuO_4 — •Felix Wirth, Thomas Lorenz, and Markus Braden — II. Physikalisches Institut, Köln, Germany

Unconventional superconductivity and magnetic correlations are expected to be closely coupled in Sr_2RuO_4. Ca- and Ti-doped Sr_2RuO_4 exhibit incommensurate (IC) spin density wave (SDW) order below about 20 K appearing at the same wave vector where IC antiferromagnetic spin fluctuations exist in the pure compound. A recent attempt to explain the magnetic order induced by Ti-doping, proposed a potential enhancement of the SDW order by applying an external charge current[1]. To prove this idea Sr_2RuO_4 single crystals doped with 25 % Ca or with 9 % Ti were grown by the optical floating zone technique. The crystal quality was greatly improved during the iterative process of crystal growth. For the investigations of the impact of currents on the SDW order, the MPMS SQUID magnetometer was adapted. No influence of currents on the SDW state was observed that could not be attributed to sample heating issues. Recorded I-U characteristics did not reveal correlations between the SDW and the electronic properties of the system. Thermal expansion shows significant differences for both cases. The thermal expansion of the Ca-doped crystal qualitatively agrees with results for higher Ca concentrations but does not indicate connections to the SDW state. A negative thermal expansion at low temperatures in the Ti-doped crystal may point to a weak correlation to the SDW state but it also resembles the behaviour in pure Sr_2RuO_4. [1]B. Zinkl, et al. Phys. Rev. Res. 3 (2021).

MA 40.20 Thu 14:00 P2/EG

Magnetic phases in the perovskite vanadate ErVO3 — •Elaheh Sadrollahi[1], Jochen Litterst[2], Tobias Ritschel[1], and Jochen Geck[1] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01069 Dresden, Germany — [2]Institut für Physik der Kondensierten Materie, Technische Universität Braunschweig, 38106 Braunschweig, Germany

The perovskite-type vanadium oxide, ErVO3, with Jahn-Teller active t2g electrons at the V site, is a prototypical correlated electron system with orbital degrees of freedom [1-3]. It features an intimate interplay between spin, orbital, and lattice interactions leading to several magnetic transitions. We have performed muSR on the perovskite vanadate ErVO3. Magnetic susceptibility, specific heat, and neutron diffraction measurements on single crystals reveal orbital ordering and orbital-flipping transitions, as well as spin ordering/spin reorientation transitions. Our muSR survey picks up these magnetic transitions and spin freezing of about 20% of the sample volume below 3 K. [1] P. Telang et al, Journal of Crystal Growth 507, 406-412 (2019) [2] P. Bordet et al. J.Solid State Chem. 106, 253 (1993) [3] M. Reehuis et al. Phys. Rev. B 73, 094440 (2006)

MA 40.21 Thu 14:00 P2/EG

Theoretical investigation of magnetic order in crystals with space group $I4_1md$ — •Maurice Colling[1] and Jan Masell[1,2] — [1]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]RIKEN CEMS, Wako, Japan

Non-collinear magnetic textures with short ranged modulation in the magnetization exhibit novel transport behavior. Such textures have been proposed to be useful in next generation magnetic memory devices. [1] Materials in the space group $I4_1md$ (#109), such as the Weyl semimetal GdAlSi, are interesting candidates for investigations in this direction because of the many potentially competing interactions. Long-ranged RKKY interaction might stabilize atomic scale spin spirals. Broken inversion symmetry generates an interfacial Dzyaloshinskii-Moriya interaction which favors Néel type spirals. Dipolar interactions, in turn, favor Bloch type helices. We derive a phenomenological Hamiltonian based on symmetry analysis and present the rich phase diagram.

[1] J. Masell, X. Z. Yu, N. Kanazawa, Y. Tokura, and N. Nagaosa, Phys. Rev. B 102, 180402 (2020).

MA 40.22 Thu 14:00 P2/EG

Crystal structural investigations of frustrated 3D spin-$\frac{1}{2}$ system $CuSn(OH)_6$ — •Kaushick Parui[1], Anton Kulbakov[1], Ellen Häussler[2], Thomas Doert[2], Vladimir Pomjakushin[3], Dmytro Inosov[1], and Darren Peets[1] — [1]IFMP, TU Dresden, Germany — [2]Professur f. Anorganische Chemie II, TU Dresden, Germany — [3]LNS, Paul Scherrer Institut, Switzerland

Copper tin hydroxide, $CuSn(OH)_6$ is an A-site-vacant double perovskite with the general stoichiometry $\square_2(BB')(OH)_6$, where B and B' are transition metals. Here, the magnetic Cu^{2+} ions sit on a face-centred sublattice, which makes the system frustrated and is expected to exhibit exotic quantum magnetism. Room-temperature x-ray diffraction performed on polycrystalline samples reveals tetragonal $P4_2/n$ symmetry, possibly with a minor monoclinic distortion. The structure is characterized by the presence of alternating corner-sharing $[Cu^{2+}(OH)_6]$ and $[Sn^{4+}(OH)_6]$ at 4d and 4c sites, respectively. Low-temperature neutron diffraction performed on deuterated powder samples accurately determined hydrogen positions. The positions of other atoms differ significantly from the previously published structure. Our proposed crystal structure of $CuSn(OH)_6$ is consistent with the tilt system $a^+a^+c^-$, as compared to the earlier proposed $a^0b^+b^+$. Magnetization measurements reveal a weak anomaly at 4.1 K suggesting a possible magnetic transition. Surprisingly, magnetic neutron diffraction revealed no long-range order down to 1.6 K. The Curie-Weiss temperature of $-7.1(3)$ K, indicating antiferromagnetic interactions, and a paramagnetic moment of $\approx 2.2\mu_B$ were also determined.

MA 40.23 Thu 14:00 P2/EG

Magnetoelastic Coupling, Grüneisen Scaling and Magnetic Phase Diagram of the Kitaev Material $Na_2Co_2TeO_6$ —

•Marius Säubert[1], Jan Arneth[1], Kwang-Yong Choi[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics, Sungkyunkwan University, Republic of Korea

We report high-resolution thermal expansion and magnetostriction measurements on the Kitaev candidate material $Na_2Co_2TeO_6$ down to low temperatures and up to high magnetic fields. Our data enable us to quantify magnetoelastic coupling and identify dominant energy scales by means of Grüneisen analysis. Combined magnetisation and magnetostriction studies reveal a hitherto unreported, field-induced crossover for $B||c$ accompanied by a sign change of $\partial T_N/\partial B$. For magnetic fields applied parallel to the honeycomb planes, magnetostriction shows that the anomaly in magnetisation at $B_C \simeq 6\,T$, which has recently been speculated to mark the onset of magnetic disorder, is connected to discontinuous lattice changes. Finally, our dilatometric studies allow us to construct the magnetic phase diagram of $Na_2Co_2TeO_6$ which displays strong hysteresis at low temperatures.

MA 40.24 Thu 14:00 P2/EG

Non-Coplanar Magnetic Orders in Classical Square-Kagome Antiferromagnets — •Martin Gembé[1], Heinz-Jürgen Schmidt[2], Ciarán Hickey[1], Johannes Richter[3,4], Yasir Iqbal[5], and Simon Trebst[1] — [1]Institute for Theoretical Physics, University of Cologne, Germany — [2]Fachbereich Physik, Universität Osnabrück, Germany — [3]Institut für Physik, Otto-von-Guericke-Universität Magdeburg, Germany — [4]Max-Planck-Institut für Physik Komplexer Systeme, Dresden, Germany — [5]Department of Physics and Quantum Centers in Diamond and Emerging Materials (QuCenDiEM) group, Indian Institute of Technology Madras, India

Motivated by the recent synthesis of $KCu_6AlBiO_4(SO_4)_5Cl$, we study the classical Heisenberg model on the square-kagome lattice – also called the squagome or shuriken lattice. This cousin of the kagome lattice exhibits, already on the classical level, a rich phenomenology of frustrated magnetism including residual entropy, order-by-disorder, and non-coplanar ordering tendencies. Having in mind that upon introducing quantum fluctuations, non-coplanar order melts into chiral spin liquids, we explore the multitude of non-coplanar orders including some which break rotational symmetry (possibly leading to nematic quantum orders), for an elementary, classical Heisenberg model on the squagome lattice supplemented by cross-plaquette interations.

MA 40.25 Thu 14:00 P2/EG

Frustrated Low-dimensional Copper Compounds Bluebellite and Rouaite. — •Aswathi Mannathanath Chakkingal[1], Falk Pabst[2], Vladimir Pomjakushin[3], Maxim Avdeev[4], Roman Gumeniuk[5], Darren Peets[1], and Dmytro Inosov[1] — [1]IFMP, TU Dresden, Germany — [2]Professur f. Anorganische Chemie II, TU Dresden, Germany — [3]PSI, Switzerland — [4]ANSTO, Australia — [5]Institut für Experimentelle Physik, TU Bergakademie Freiberg, 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 bluebellite ($Cu_6[(IO_3)(OH)_3](OH)_7Cl$) and rouaite ($Cu_2(NO_3)(OH)_3$). Neutron diffraction studies were performed to determine both compound's crystal structure and magnetic structure. $Cu_2(NO_3)(OH)_3$ crystallizes in a monoclinic structure consisting of a ferromagnetic chain and an antiferromagnetic chain of Cu^{2+}. This is similar to the botallackite ($Cu(OH)_3Br$) in which spinon-magnon mixing was recently reported. $Cu_6[(IO_3)(OH)_3](OH)_7Cl$ crystallizes in a trigonal structure, and the magnetic Cu^{2+} forms a distorted maple-leaf lattice. Frustration effects and quantum fluctuations in spin-1/2 maple-leaf lattice antiferromagnets may give rise to interesting phenomena. We report details of the crystal structure, magnetic structure, and the low-temperature magnetic and thermal properties.

MA 40.26 Thu 14:00 P2/EG

Variational iPEPS — •Erik Weerda[1], Jan Naumann[2], Matteo Rizzi[2], Jens Eisert[1], and Philipp Schmoll[1] — [1]Institute for Theoretical Physics, University of Cologne, D-50937 Köln, Germany — [2]Dahlem Center for Complex Quantum Systems and Institute for Theoretical Physics, Freie Universität Berlin, 14195 Berlin, Germany

Tensor networks capture large classes of ground states of phases of quantum matter faithfully and efficiently. Their manipulation and contraction has remained a challenge over the years, however. For most of the history of projected entangled pair states, ground state simulations of two-dimensional quantum lattice systems using (infinite) projected entangled pair states have relied on what is called a time-evolving block decimation. In recent years, multiple proposals for the variational optimization of the quantum state have been put forward, overcoming accuracy and convergence problems of previously known methods. The incorporation of automatic differentiation in tensor networks algorithms has ultimately enabled a new, flexible way for variational simu- lation of ground states and excited states. In this work, we present and explain the functioning of an efficient, comprehensive and general tensor network library for the simulation of infinite two-dimensional systems using iPEPS, with support of different lattice geometries, flexible unit cells, the use of symmetries and GPU calculations.

MA 40.27 Thu 14:00 P2/EG

Charge dynamics in doped frustrated magnets and quantum spin liquids — •Luke Staszewski and Alexander Wietek — Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

The advent of recent developments in algorithms, namely finite temperature tensor network related algorithms, has opened the doors to a serious numerical testbed for investigating the plethora of interesting phenomenology in strongly interacting electron systems. This testbed is taking us a step closer to understanding an array of systems displaying unconventional superconductivity as well as helping answer questions about the delicate interplay between magnetic correlations and the onset of superconductivity in such materials. This work looks at how the mobility of holes is affected by various magnetic environments and vice versa in the hope to shed some more light on the nature of the mechanisms at play in the resulting phases that have recently been demonstrated both numerically and experimentally. We focus on the role geometric magnetic frustration plays in leading to both unconventional superconductivity, and exotic magnetic order, such as quantum spin liquids.

MA 40.28 Thu 14:00 P2/EG

Micromagnetic simulation of magnetic reversal processes in exchange biased thin film geometries — •Lukas Paetzold, Sapida Akhundzada, Christian Janzen, 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

As first observed by Meiklejohn and Bean [1] and described as a unidirectional anisotropy, the exchange bias 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 thin film systems with a polycrystalline uncompensated antiferromagnetic layer. Different geometries like stripes, squares and discs in the micrometer range are simulated and the influence of modified magnetic parameters in the edges is investigated.

[1] W. H. Meiklejohn et al., Phys. Rev. 105, 904 (1956)
[2] A. E. Berkowitz et al., J. Magn. Magn. Mater. 200, 552-570 (1999)
[3] D. Engel et al., J. Magn. Magn. Mater. 293, 849-853 (2005)
[4] J. Nogués et al., J. Magn. Magn. Mater. 192(2), 203-232 (1999)
[5] A. Vansteenkiste et al., AIP Advances 4, 107133 (2014)
[6] J. De Clercq et al., J. Phys. D: Appl. Phys. 49, 435001 (2016)

MA 40.29 Thu 14:00 P2/EG

Magneto-ionic control of magnetic properties in perpendicular magnetized synthetic antiferromagnet stacks — •Maria-Andromachi Syskaki[1], Takaaki Dohi[2,3], Mona Bhukta[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 — [3]Laboratory for Nanoelectronics and Spintronics, Research Institute of Electrical Communication, Tohoku University, Sendai, Japan

Voltage-controlled spintronic devices are the key to a more energy-efficient way for future storage applications [1]. Electric field effect experiments in this direction reported that the application of a low-power ionic liquid gating technique [2] to nearly compensated synthetic antiferromagnet (SAF) stacks gives rise to high domain wall velocities [3]. In our work, we have grown a SAF stack by magnetron sputtering consisting of two ferromagnetic layers coupled by a non-magnetic spacer layer. The coupling strength is modified by tuning the thickness of the spacer layer to investigate the electric field modulation. With room temperature voltage-controlled magneto-ionic effects, we focus on the modulation of the magnetic properties in this system, i.e., the control of the compensation ratio, the perpendicular magnetic anisotropy, and the antiferromagnetic RKKY coupling strength. [1] T. Nozaki et al., Micromachines 10(5), 327 (2019). [2] C. Leighton et al., Nature Mater 18, 13 (2019). [3] Y. Guan et al., Nat. Commun. 12, 5002 (2021).

MA 40.30 Thu 14:00 P2/EG

Exchange bias in PtMn/Co: New insights into its origin and possibilities for manipulation — •Beatrice Bednarz[1], Maria-Andromachi Syskaki[2], Rohit Pachat[3], Liza Herrera-Diez[3], Armin Kleibert[4], Mathias Kläui[1], and Gerhard Jakob[1] — [1]Johannes Gutenberg-University, Mainz, Germany — [2]Singulus Technology AG, Kahl, Germany — [3]Université Paris-Saclay, Palaiseau, France — [4]Paul Scherrer Institute, Villigen PSI, Switzerland

Exchange bias is fundamental for many spintronic devices as a means of pinning the direction of the ferromagnetic layer [1,2] and for exerting an intrinsic magnetic field for field-free switching [3]. One of the most commonly used antiferromagnets for this purpose is PtMn [4]. It has a CuAu-I type structure with a high bulk Néel temperature of 975 K and high thermal stability [4]. In this study, we report on new insights into its magnetic structure and the effect on the exchange bias. The magnetic domains were imaged for crystalline as well as polycristalline PtMn by x-ray magnetic linear dichroism (XMLD) photo-emission electron microscopy (PEEM). We found that the drastic difference in the exchange bias is not caused by a difference in the domain size but only by differences in the domain orientations. Furthermore, we show that the magnetic properties of the exchange biased system can be reversibly controlled by ionic liquid gating.

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MA 40.31 Thu 14:00 P2/EG

Relaxation behavior of antiferromagnetic grains in polycrystalline exchange-biased bilayers — •Maximilian Merkel, Rico Huhnstock, Meike Reginka, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Measuring first-order reversal curves, a prototypical polycrystalline exchange-biased bilayer was found to exhibit a viscous decrease of the ferromagnetic in-plane magnetization upon increasing the external magnetic field. [1] The observed phenomenon is mediated by a rotatable magnetic anisotropy arising from thermally unstable antiferromagnetic grains coupled to the probed ferromagnet. The investigations, performed with the help of angular-resolved vectorial Kerr magnetometry and Kerr microscopy, are further in agreement with a generalized description of polycrystalline exchange-bias systems. The study emphasizes the relevance of understanding minor loop behavior addressing non-saturated magnetic states for systems susceptible to dynamic changes on the hysteresis loop timescale.

[1] Merkel et al., Phys. Rev. B 104, 214406 (2021)

MA 40.32 Thu 14:00 P2/EG

Tailoring the electronic and magnetic properties of the layered antiferromagnet $CrCl_2$ — •Diana Vaclavkova, Vladyslav Romankov, Niéli Daffé, and Jan Dreiser — Swiss Light Source (SLS), Paul Scherrer Institut (PSI), CH-5232 Villigen PSI, Switzerland

The electronic and magnetic properties of two-dimensional van der Waals (vdW) materials differ greatly when comparing mono- and few-layered flakes to their bulk counterparts. In the case of atomically thin single layers the substrate has a profound influence on their properties. $CrCl_2$, belonging to the family of vdW materials, is expected to show a geometrical frustration in the monolayer limit given antiferromagnetic interactions are present [1]. Our preliminary studies involve X-ray magnetic circular dichroism measurements of mono- and few-layered $CrCl_2$ deposited on different materials. Based on the initial interpretation of the experimental data, methods for tailoring the magnetic properties by careful choice of the substrate material will be discussed.

[1] McGuire, M. A. (2017). Crystal and magnetic structures in layered, transition metal dihalides and trihalides. Crystals, 7(5), 121.

MA 40.33 Thu 14:00 P2/EG

Angle dependent FMR studies on YIG films — •Tim Vogel[1], David Breitbach[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Yttrium iron garnet (YIG) is a commonly used material in magnonics due to its low spin-wave damping. Previous ferromagnetic resonance spectroscopy (FMR) studies on (111) grown YIG thin films suggested a deviation from the expected sixfold symmetry of the magnetocrystalline anisotropy for large external fields. For more in-depth investigations, we developed a fully automized setup for angle dependent vector-network-analyzer-FMR studies of in-plane magnetized YIG films. We apply this setup to investigate a (111) grown, d=55nm thick LPE YIG film. Our results confirm the expected sixfold symmetry even for high external field values. Further, we apply the setup to quantify the effect of the present anisotropy field. This study contributes to the understanding of YIG thin films and the impact of magnetocrystalline anisotropy for magnonic applications.

This research is funded by the DFG - Project No. 271741898 and TRR 173-268565370 (B01) and the ERC Grant No. 101042439 'CoSpiN'.

MA 40.34 Thu 14:00 P2/EG

Quantification of anisotropic and magneto-elastic contributions to the SSW excitation in Bi:YIG films via UXRD — •Steffen Peer Zeuschner[1], Xi-Guang Wang[3,4], Marwan Deb[1], Elena Popova[5], Gregory Malinowski[6], Michel Hehn[6], Alexander von Reppert[1], Nils Keller[5], Jamal Berakdar[4], and Matias Bargheer[1,2] — [1]Universität Potsdam, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, 12489 Berlin, Germany — [3]Central South University, Changsha 410083, China — [4]Martin-Luther Universität, 06099 Halle/Saale, Germany — [5]Institut de Physique de Rennes (IPR, CNRS) UMR6251 Université Rennes, 35000 Rennes, France — [6]Institut Jean Lamour (IJL, CNRS) UMR 7198, Université de Lorraine, 54506 Vandaeuvre-lès-Nancy, France

The photoexcited standing spin waves (SSWs) in the ferromagnetic insulator Bi:YIG are generated by the ultrafast change of the magnetocrystalline anisotropy and the picosecond strain dynamics via magneto-elasticity. Ultrafast X-ray diffraction (UXRD) quantifies the strain and temperature spatio-temporally which is used as in input to a numerical micromagnetic model to fit the ultrafast time-resolved magneto-optical Kerr-effect (tr-MOKE) data of the thin film which exhibits SSWs. With this, we prove that both mechanisms drive the fundamental mode with opposite phase. Both mechanisms are also substantially active as the relative amplitude of the higher order modes indicates. This is a prime example for the exceptional assistance UXRD offers in the understanding and modelling of ultrafast magnetic phenomena.

MA 40.35 Thu 14:00 P2/EG

Generating small magnetic fields inside an open-end magnetic shielding with a superconducting solenoid magnet — •Lukas Vogl[1,2], Ana Strinc[1,2,3], Franz Haslbeck[1], Rudolf Gross[1,2,3], and Nadezhda Kukharchyk[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 Technologies, München, Germany

Quantum memory is an essential part for the development of quantum computers. One of the most promising realisation of quantum memories has been realised for storage of optical photons in rare-earth-doped crystals, reaching a storage time of 6 hours. The long storage time has been achieved due to working at the zero first-order Zeeman shift point (ZEFOZ). At this point, the phase-sensitivity of a spin system to the magnetic field fluctuations is strongly reduced, and thus longer coherence times can be achieved. Such ZEFOZ transitions are present in the hyperfine states of rare earth ions close to zero magnetic fields, which enables the design of quantum memories compatible with the zero-field environments required for superconducting quantum computing curcuits. Here, we present a setup for a highly controllable homogeneous magnetic environment with additional shielding from external background magnetic fields. This environment will allow for precise control of the magnetic field at the sample position, fine tuning to the ZEFOZ transitions, and additional protection of the superconducting quantum circuits from the fields applied to the rare earth spins.

MA 40.36 Thu 14:00 P2/EG

Design and set-up of an optomechanical readout apparatus to characterize magnetic field sensors encompassing high-Q resonators down to 4 K — Torben Hänke, •Dhavalkumar Mungpara, and Alexander Schwarz — Institute of Nanostructure and Solid State Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg

This work has been conducted as part of the OXiNEMS project that aims to realize an miniaturized all-oxide hybrid sensor able to detect magnetic fields in the fT-regime. Our envisaged design encompasses a superconducting pick-up loop with a constriction and a magnetically sensitive high-Q resonator placed directly above it.

Here, we present a set-up to characterize the mechanical properties of potential resonators alone or already integrated into the hybrid sensor. To do so, the resonator motion is detected using an all-fiber interferometer inside a dip stick, which can be pumped to pressures below 10^{-6} mbar and cooled down to 4 K. Alignment between fiber and resonator in x-, y- and z-directions is done with remotely operated precision piezomotors. The resonator can be excited using an integrated shaker piezo to record amplitude and phase response curves. Without external excitation the power spectral density can be recorded and to test the performance of the complete hybrid sensor in operation, the frequency change of the resonator can be monitored.

The OXiNEMS project (www.oxinems.eu) has received funding from the European Union‘s Horizon 2020 research and innovation program under Grant Agreement No. 828784.

MA 40.37 Thu 14:00 P2/EG

Micro-Hall magnetometry for multiscale magnetic measurements — •Bereket Ghebretinsae[1], Charu Garg[1], Martin Lonsky[1], Mohanad Al Mamoori[1], Michael Huth[1], Christian Schröder[2], Priscila Rosa[3], and Jens Müller[1] — [1]Institute of Physics, Goethe University, 60438 Frankfurt (M), Germany — [2]Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Bielefeld 33619, Germany — [3]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

Micro-Hall magnetometry is a technique that allows for ultra-sensitive magnetic stray field measurements on macro- to micro- to nanoscaled samples. The magnetometer is a Hall sensor that utilizes the very high electron mobility of a two-dimensional electron gas inside a GaAs/AlGaAs heterostructure to resolve even smallest changes in the sample's stray field almost instantaneously. The technique is unique especially in its versatility. Firstly, the Hall sensor itself can serve as a substrate for the growth of nanoscaled magnetic samples with complex geometries. Secondly, microscopic and even macroscopic samples can be placed directly ontop of the sensor surface such that the stray field emanating from the surface of the sample is captured by the Hall sensor. Here we demonstrate the utility of this technique using (i) 3D ferromagnetic FeCo nanostructures and (ii) single crystalline microsized $Eu_5In_2Sb_6$ with two antiferromagnetic transitions. We present magnetic field- and temperature dependent micro-Hall measurements to explain the details of the technique and prove its usefulness as a tool for the study of multiscale magnetic phenomena.

MA 40.38 Thu 14:00 P2/EG

PUMA: Thermal neutron three axes spectrometer — •Alsu Gazizulina[1], Avishek Maity[2], Jitae Park[2], and Frank Weber[1] — [1]Institute of Quantum Materials and Technologies, Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany — [2]Heinz Maier-Leibnitz Zentrum, Technical University of Munich, Garching, Germany

Thermal neutron three axes spectrometer PUMA is characterized by a very high neutron flux as a result of the efficient use of focusing techniques. An innovative option of the spectrometer is the multi-analyzer/detector system, which allows a unique and flexible type of multiplexing. Using this option, a scattering angle range of 16° can be measured simultaneously and flexible $Q - \omega$ paths can be realized without repositioning the instrument. The typical scientific applications of PUMA are studies of phonons and magnons. Furthermore, a unique feature of the instrument is the possibility to perform stroboscopic, time resolved measurements of both elastic and inelastic signals on time scales down to the microsecond regime. Using this technique, the sample is periodically perturbed by an external variable such as temperature, electric field, etc. The signal is then recorded not only as a function of momentum and energy transfer, but also given a time stamp, relative to the periodic perturbation. Since 2021, the Neutron Scattering Group of the Institute of Quantum Materials and Technologies (IQMT) of the Karlsruhe Institute of Technology (KIT) has been jointly operating the PUMA three-axes spectrometer at MLZ within the framework of a collaboration contract.

MA 40.39 Thu 14:00 P2/EG

Pulse-triggered detection of resonant magnetic small-angle scattering at a laser-driven X-ray source — •Leonid Lunin[1], Martin Borchert[1], Daniel Schick[1], Bastian Pfau[1], and Stefan Eisebitt[1,2] — [1]Max-Born-Institut, Berlin, Germany — [2]Technische Universität, Berlin, Germany

Resonant soft-x-ray scattering methods provide unique possibilities to study nanometer-scale magnetization dynamics on ultrashort timescales. Typically, these experiments are performed at synchrotron-radiation (SR) sources or x-ray free-electron lasers (XFELs) due to the required tunability and intensity of the radiation. While XFELs still offer only limited access, the available time resolution at SR sources on the order of 100 ps is insufficient for many phenomena in ultrafast magnetism. We developed an instrument based on a laser-driven plasma x-ray source to perform resonant x-ray scattering in the wavelength regime between 50 eV and 1500 eV with pulses of 10 ps duration. Specifically, we here present the first resonant small-angle x-ray scattering experiment on a laboratory scale with photon energies in the range of the transition-metal L edges and the rare-earth-metal M edges. In our pilot experiment, we detect scattering from domains forming in a ferrimagnetic Fe/Gd multilayer using an electronically triggered hybrid detector with single-photon sensitivity. Such laboratory-based measurements will allow studying magnetization dynamics with high spatio-temporal resolution in a much more efficient and flexible way than possible today.

MA 40.40 Thu 14:00 P2/EG

Quantitative high sensitivity Magnetic Force Microscopy in vacuum — •Christopher Habenschaden[1], Sibylle Sievers[1], and Andrea Cerreta[2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Park Systems Europe GmbH, Mannheim, Germany

Magnetic Force Microscopy (MFM) allows the imaging of magnetic samples with spatial resolution of tens of nm and stray field resolution down to the mT range. However, it lacks comparability between measurements, which can be overcome by calibrating the tip, using a magnetic reference sample. This enables the calculation of sample stray fields in A/m, allowing quantitative MFM measurements.

Spatial resolution and field sensitivity can be pushed to several nm and the hundred uT range by measuring in vacuum conditions. This is due to the higher cantilever quality factors Q, that can be achieved in vacuum, directly leading to an increase in measurement signal. However, with increasing signal amplitude, non-linear behavior must be considered. Additionally, advanced feedback techniques are required for stable operation in vacuum.

Here we present an implementation by using phase-locked loops into a commercial Atomic Force Microscope (Park NX Hivac AFM), overcoming non-linearities in measurement signal. This allows stable, transfer function based, quantitative MFM also in vacuum. Advances in resolution and sensitivity are discussed and measurements on samples like skyrmion hosting multilayer stacks are shown and analyzed to demonstrate the feasibility of our measurement approach.

MA 40.41 Thu 14:00 P2/EG

Development of an AC susceptometer for magnetic thin film systems — •Matthias Zetzl, Grace Causer, and Christian Pfleiderer — Physik-Department, Technical University of Munich, D-85748 Garching, Germany

An ongoing challenge in thin film magnetism concerns the need for easy-to-use characterization tools exploiting the response to alternating magnetic fields. We report the development of a bespoke ac-susceptometer comprising a primary and a balanced pair of secondaries specifically tailored for thin film systems. To gauge the performance of the susceptometer we have revisited the properties of epitaxial layers of MnSi in the thick film limit, in which high-resolution measurements of the temperature and field history of the magnetization, complemented by neutron scattering and neutron reflectometry, have recently identified the formation of a cascade of solitonic layers.

MA 40.42 Thu 14:00 P2/EG

Comparison of continuous and pulsed neutron sources for MIEZE witz McStas. — •Korbinian Fellner[1], Johanna K.

Jochum[1], Lukas Vogl[1], Lukas Beddrich[1], Jonathan Leiner[1], Christian Franz[2], and Christian Pfleiderer[3] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [2]Jülich Centre for Neutron Science JCNS-MLZ, Germany — [3]Physik-Department, Technische Universität München, Germany

The MIEZE method is a type of the neutron spin-echo technique that uses oscillating neutron intensities to record changes to the energy of a scattered neutron. This allows MIEZE, which is implemented at the spectrometer RESEDA to study magnetic dynamics, quantum phenomena, and molecular diffusion in soft matter, to achieve an energy resolution of neV, taking advantage of a broad wavelength band of $\Delta\lambda/\lambda$=11.6 %. Nonetheless, a significant portion of the neutron beam is discarded by the velocity selector, making MIEZE at pulsed neutron sources increasingly attractive. We have implemented the polarization shaping components of RESEDA in the McStas framework to investigate the feasibility and data reduction of a MIEZE spectrometer at a pulsed neutron source (PNS). The large wavelength spread of a PNS allows for the measurement of the intermediate scattering function over many points in Fourier time, similar to a multi-detector option at a triple-axis spectrometer. Simulations of a quasielastic sample enable a comparison of the performance between a reactor source and a PNS. Additionally, tests of crucial data reduction algorithms that have not been addressed in previous instrument proposals, are discussed.

MA 40.43 Thu 14:00 P2/EG

Characterizing the defocusing behaviour of magnetic microparticles for the application in three-dimensional trajectory tracking — •Nikolai Weidt, Rico Huhnstock, Yahya Shubbak, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

For the implementation in Lab-on-a-chip systems, superparamagnetic particles can be surface-functionalized to bind to specific analytes [1]. Making use of the transport of particles above magnetically stripe-patterned exchange bias layer systems is a promising approach to achieve a remote-controlled and directed transport of these particles [2]. The trajectories of particles during transport can be evaluated for detection of analyte binding events. To get access to the third dimension in optical microscopy, the image characteristics of particles moving out of the focal plane during transport steps are analyzed [3]. In this work quantization of defocusing is achieved by determining the Tenenbaum gradient of single particle images. Correlation between Tenenbaum gradient and the particle's vertical position is established by moving the particles in z-direction through the focal plane of the microscope defined steps. Here we show Tenenbaum gradient curves for differently composed particles and changing illumination conditions.
[1] Rampini et al. (2016) Lab on a Chip, 16(19), pp. 3645-3663. [2] Holzinger et al. (2015) ACS Nano, 9(7), pp. 7323-7331. [3] Tasadduq et al. (2015) Flow Measurement and Instrumentation, 45, pp. 218-224.

MA 40.44 Thu 14:00 P2/EG

Simulation of Interaction and Self-assembly of Magnetically Decorated Particles — Sibylle Gemming, •Maximilian Neumann, and Aaron Steinhäusser — TU Chemnitz, Chemnitz, Germany

Magnetic particles with the ability to self-assemble allow for the creation of complex structures from simple parts while retaining malleability, enabling easy manipulation through external influences (e.g. magnetic fields). By arranging permanent magnets along the edges of particles in specific patterns we can assign (multiple) unique patterns to different species of particles without introducing additional geometric limitations. This kind of magnetic assembly schemes improves the selectivity between different types of particles and promotes fixed orientations between those on assembly. Our work shows different simulations of assembly schemes with a focus on finding optimal parameters to maximize interaction and selectivity.

MA 40.45 Thu 14:00 P2/EG

Giant Magnetic Resistance sensor array directly on board — •Laila Bondzio, Torben Tappe, and Andreas Hütten — Bielefeld University, Germany

GMR multilayer systems of Py/Cu-bilayers exhibit nearly triangular shaped GMR curves with a high sensitivity, which is desirable for sensor applications. With a grid of multiple sensor elements a two dimensional magnetic landscapes can be mapped as changes in a magnetic field. To organize and contact a large number of sensor elements on a wide spread area of few centimeters it might be useful to sputter the structure directly onto contacts on a circuit board. Although the circuit board is not an ideal substrate, it has been shown that such application is feasible.

MA 40.46 Thu 14:00 P2/EG

Multifunctional Magneto-Optical Sensing of Temperature and Magnetic Field — •Michael P. Path, Finn Klingbeil, and Jeffrey McCord — Institute of Materials Science, Kiel University, Germany

Measurements of temperature and magnetic field are vital in laboratory and industry settings. We demonstrate multi-functional magneto-optical measurement schemes to relate magnetic and micromagnetic features to temperature and magnetic field using magneto-optical active iron garnet films. The focus lies upon a dual quadrature polarimetric measurement scheme. A calibration free temperature measurement using the relation of the first and third harmonic of the obtained signal during a magnetic sinusoidal excitation of the garnets is presented. Using the domain wall susceptibility a limit of detection of the magnetic field below 14 $\mathrm{nT}/\sqrt{\mathrm{Hz}}$ is reached. Indirect measurements of current in integrated circuits is demonstrated using spatially resolved magnetic field sensitivity utilizing a direct magneto-optical imaging setup. A connection of field and temperature measurements in magneto-optical imaging is discussed.
We acknowledge the DFG for funding through grant MC 9/20-2.
F. Klingbeil, S.D. Stölting, J. McCord, APL 118, 092403 (2021)

MA 40.47 Thu 14:00 P2/EG

Supervised folding of magnetic origami actuators using highly compliant magnetic field sensors — •Eduardo Sergio Oliveros-Mata[1], Minjeong Ha[1,2], Gilbert Santiago Cañón Bermúdez[1], Jessica A.-C. Liu[3], Benjamin A. Evans[4], Joseph B. Tracy[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Gwangju Institute of Science and Technology, Gwangju, South Korea — [3]North Carolina State University, Raleigh, NC, United States — [4]Elon University, Elon, NC, United States

Soft actuators are mechanically active functional systems. Magnetic polymeric composites have been used as grippers, rollers, and walkers responding to applied magnetic fields. Flexible, light and conformal sensory systems are still under research to have on-board control of the actuation of soft systems. Here, we show electronic skins with magnetic field sensors that provide awareness of the folding state of origami-like magnetic foils.
[1] M. Ha, E.S. Oliveros Mata, et al. Adv. Mater. 33, 2008751 (2021)

MA 40.48 Thu 14:00 P2/EG

Single magnetic domain magnetoelectric composites for picotesla field sensing — •Dennis Seidler, Patrick Hayes, Lars Thormählen, Dirk Meyners, Eckhard Quandt, and Jeffrey McCord — Kiel University, Institute for Materials Science, Kaiserstraße 2, 24143 Kiel, Germany

The contactless measurement of biomagnetic signals i.e., magnetocardiography or magnetoencephalography at ambient conditions has gained high interest for medical applications. Magnetoelectric (ME) cantilever-based field sensors have shown promising results in that regard [1]. To achieve the necessary limit of detection (LOD) a minimization of all noise sources has to be performed. Magnetic noise mainly results from magnetic domain wall activity during sensor operation. We demonstrate a single-domain thick magnetic multilayer stack, to minimize the magnetic noise in the ME sensors. The multilayer is prepared via sputter deposition in an applied magnetic field. We utilize a scalable approach based on magneto-statically coupled $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$ layers, with the magnetic sensitive layer showing single domain behavior while still achieving high field sensitivity. Integrated in converse ME composite sensors, we obtain a LOD of 40 $\mathrm{pT}\cdot\mathrm{Hz}^{-0.5}$ at 10 Hz.
This work was funded by the German Research Foundation (DFG) through the Collaborative Research Centre CRC 1261.
[1] P. Hayes, M. Jovičević Klug, S. Toxværd, P. Durdaut, V. Schell, A. Teplyuk, D. Burdin, A. Winkler, R. Weser, Y. Fetisov, M. Höft, R. Knöchel, J. McCord, and E.Quandt, Sci Rep. 9, 16355 (2019)

MA 40.49 Thu 14:00 P2/EG

Spin-transfer torque ferromagnetic resonance in vortex magnetic tunnel junctions — •Johannes Demir, Karsten Rott, and

Günter Reiss — Bielefeld University, Germany

We investigate the gyrotropic mode resonance frequency of the vortex as the free layer of a magnetic tunnel junction (MTJ) by means of spin-transfer torque ferromagnetic resonance (STT-FMR) using a two-port vector network analyzer (VNA). In order to obtain a proper resistance-area (RA) product the capping layer of a commercial wafer was mostly etched down to sputter 8.5 nm permalloy as the vortex layer on top of it afterwards. Subsequently, nanopillars of 300 and 600 nm diameter were fabricated using electron-beam lithography. Using a coplanar-waveguide to feed the GHz-range current through the nanopillar the transmission scattering-parameter S_{21} was determined. Resonance frequencies of around 240 and 150 MHz for the 300 and 600 nm diameter samples, respectively, were measured in accordance with literature [1]. We recognize a shift of the frequency with increasing the bias voltage indicating a DC-STT contribution.

[1] V. Novosad et al., Phys. Rev. B **72**, 024455 (2005)

MA 40.50 Thu 14:00 P2/EG

Growth and magnetic properties of Fe/Pt heterostructures with L10-FePt alloyed interface — Laura Scheuer[1] and •Evangelos Th. Papaioannou[2] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663, Kaiserslautern, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany

The growth of Fe/L10FePt/Pt trilayers was achieved by means of electron beam evaporation technique and appropriate annealing. We show the formation of the L10 alloy for the case of Fe(12nm)/Pt (6nm) [1] and we investigate the formation of L10 phase for Fe,Pt thicknesses smaller than 3 nm. Magneto-optical and Squid magnetometry reveal the strong change in the magnetization reversal when the L10 phase appears. Furthermore, ferromagnetic resonance studies show a large enhancement of the gilbert damping parameter for the alloyed interface. Mumax simulations are implemented in order to understand the role of the L10 in the magnetic properties of the heterostructures.

[1] L.Scheuer et al., iScience25, 104319, (2022)

MA 40.51 Thu 14:00 P2/EG

Light-poling of antiferromagnetic domains in a magnetoelectric $LiCoPO_4$ — •Jakub Vit[1,2], Oleksiy Pashkin[3], Vilmos Kocsis[4], Yasujiro Taguchi[5], Istvan Kezsmarki[6], and Sandor Bordacs[1] — [1]Budapest University of Technology and Economics, Hungary — [2]Institute of Physics, Czech Academy of Sciences, Czechia — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]Institut für Festkörperforschung, Leibniz IFW-Dresden, Germany — [5]RIKEN Center for Emergent Matter Science (CEMS), Japan — [6]University of Augsburg, Germany

We selected antiferromagnetic domains in a magnetoelectric $LiCoPO_4$ single crystal by illuminating the sample by light while cooling through the Néel temperature. The experimental results and symmetry analysis indicate that the thermal gradient and resulting heat flow are responsible for such a novel effect: Propagation of thermally-activated quasi-particles is nonequivalent in different antiferromagnetic domains. The microscopic mechanism behind the observed effect is not clear at the moment, calling for future theoretical modeling.

MA 40.52 Thu 14:00 P2/EG

Spontaneous nanoscale square vs. hexagonal skyrmion lattices in Fe/Ir(111) — •Mara Gutzeit, Soumyajyoti Haldar, Tim Drevelow, Moritz A. Goerzen, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany

We investigate the occurrence of spontaneous skyrmion lattices in an Fe monolayer in both fcc and hcp stacking on the Ir(111) surface employing first-principles calculations based on density functional theory (DFT). For fcc-Fe the well-known non-collinear square nanoskyrmion lattice is confirmed as the magnetic ground state [1]. Surprisingly, for hcp-Fe a nearly collinear hexagonal multi-Q state turns out energetically more favourable than the hexagonal skyrmion lattice proposed based on spin-polarized scanning tunneling microscopy experiments [2]. By mapping total DFT energies of a variety of complex magnetic structures to an atomistic spin model we reveal the interplay of pairwise Heisenberg exchange, Dzyaloshinskii-Moriya interaction and higher-order exchange interactions to be responsible for the symmetry and the degree of collinearity of the respective spin lattice.

[1] Heinze *et al.* Nat. Phys. **7**, 713 (2011)
[2] von Bergmann *et al.* Nano Lett. **15**, 3280 (2015)

MA 40.53 Thu 14:00 P2/EG

Temperature dependent μ-ARPES of the exfoliated zigzag-type intralayer antiferromagnet FePS3 — •B. Pestka[1], J. Strasdas[1], A. K. Budniak[2], D. Baranowski[3], N. Leuth[1], H. Boban[3], M. Liebmann[1], V. Feyer[3], L. Pulcinski[3], E. Lifshitz[2], and M. Morgenstern[1] — [1]II Institute of Physics B and JARA-FIT, RWTH Aachen University, Germany — [2]Schulich Faculty of Chemistry, Solid State Institute of Thechnology, Haifa 3200003, Israel — [3]Forschungszentrum Jülich, Peter Grünberg Institute (PGI-6), Germany

The exfoliable intralayer antiferromagnets MPX3 (M: transition metal, P: phosphorus, X: chalcogenide) provide a multitude of spin arrangements such as Néel-, stripe- and zigzag-type. However, the electronic band structure of these semiconductors has barely been probed. Here, we provide micro-scale angle-resolved photoelectron spectroscopy (μ-ARPES) of the exfoliated intralayer antiferromagnet FePS3 above and below the Néel temperature TN. The material exhibits the zig-zag-type spin arrangement consisting of ferromagnetic zig-zag lines that are mutually coupled antiferromagnetically. We find changes of some of the probed bands across TN. Additionally, the changing bands differ in the different Gamma-K directions, if probed below TN, which is likely related to the selected orientation of the ferromagnetic zig-zag stripes. First low-temperature scanning tunneling spectroscopy results obtained with a Cr tip are also presented. The novel access to the electronic band structure will contribute to a detailed understanding of 2D antiferromagnets.

MA 40.54 Thu 14:00 P2/EG

Optimised mechanical exfoliation of antiferromagnetic $MnPS_3$ — •Niklas Leuth — II. Institute of Physics B, RWTH Aachen University, Aachen, Germany

An optimized mechanical exfoliation technique was developed to exfoliate large-area few-layer flakes of the antiferromagnetic van-der-Waals material $MnPS_3$. This was achieved by utilizing the process of oxygen plasma ashing on gold surfaces and making use of the good bonding strength between the gold surface and the sulfur atoms which terminate the individual layers of $MnPS_3$. Furthermore, there is evidence that the gold surface of the substrate gets oxidised by the oxygen plasma. With the optimised technique, it was possible to exfoliate $\sim 100\,\mu m^2$-large mono- and bilayer flakes. Furthermore, a method was developed which characterises the layer thickness of the exfoliated flakes quantitatively based on the optical Michelson contrast.

MA 40.55 Thu 14:00 P2/EG

Dual-pulse-excitation all-optical switching of a $Gd_{26}Fe_{74}$ ferrimagnet — •Rahil Hosseinifar[1], Ivar Kumberg[1], Sangeeta Thakur[1], Sebastien Hadjadj[1], Jendrik Gordes[1], Chowdhury Awsaf[1], Mrio Fix[3], Florian Kronast[2], Manfred Albrecht[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Institut für Physik, Universität Augsburg, Universitätsstraße 1, Augsburg, Germany

Individual linearly *p*-polarized laser pulses of 800 nm wavelength above a specific threshold fluence can reverse the magnetization of ferrimagnetic samples. We study this all-optical toggle switching in $Gd_{26}Fe_{74}$ ferrimagnetic alloys with out-of-plane easy axis of magnetization after dual-pulse excitation by x-ray magnetic circular dichroism photoelectron emission microscopy. The time between the two spatially overlapped pulses is varied. The experiment is done at room temperature and at 70 K, above and below the magnetic compensation temperature of the sample. In both cases, when the time delay is less than 1 ps, the threshold for toggle switching decreases. At $T = 70$ K, all the region in the footprint of the laser pulse above a certain fluence switches deterministically. However, at room temperature, in addition to a region of deterministic switching, another region appears at higher fluences where multi-domain nucleation is observed.

MA 40.56 Thu 14:00 P2/EG

Magnetoelastic coupling and magnetic anisotropy in $LiMnPO_4$ — •Timo Kleinbek[1], Sven Spachmann[1], Martin Jonak[1], Mahmoud Abdel-Hafiez[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Department of Physics and Astronomy, Uppsala University, Sweden

We report high-resolution capacitance dilatometry, magnetisation, and high-frequency electron-spin-resonance studies on $LiMnPO_4$ single crystals. Our findings imply sizeable magnetoelastic coupling as demonstrated by large anomalies in the thermal expansion coefficients associated with the evolution of long-range magnetic order at $T_N = 33$ K. We extract the uniaxial pressure dependencies. Existence of short-range magnetic order above T_N is indicated by magnetic entropy changes up to around 70 K. A spin flip for $B||b$-axis is indicative of a Dzyaloshinskii-Moriya-interaction-caused spin-canting in the ground state. The magnetic phase diagrams are constructed for the three crystallographic directions. The field dependence of the magnon branches implies a two-sublattice model of antiferromagnetic resonance with orthorhombic anisotropy. An anomalous magnon branch detected above the spin-flop field is shown to be accountable-for by a rotation of the easy anisotropy axis at the spin-flop field by 6.5° away from the a-axis towards the hard b-axis. With increasing temperature, the two zero-field excitation gaps remain distinct, implying the preservation of the orthorhombic anisotropy.

MA 40.57 Thu 14:00 P2/EG

Magnetoelastic coupling and uniaxial pressure dependencies of AFM ordering in 2D vdW $M_2P_2S_6$(M=Ni & Fe) — •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(vdW) magnets research has been intensified recently due to their myriad of applications. For these applications, an understanding of coupling of the mechanical degrees of freedom to electronic and magnetic order is crucial. In this work, we employed thermodynamic methods to study the magnetoelastic coupling in 2D vdW $Fe_2P_2S_6$ and $Ni_2P_2S_6$. These materials belong to the class of transition metal chalcogenophosphates($M_2P_2S_6$), with XXZ- and Ising type antiferromagnetic order respectively. *M(T)* and $C_p(T)$ on single crystals confirm AFM ordering in both $Fe_2P_2S_6$(T_N=118 K) and $Ni_2P_2S_6$(T_N=158 K). Our thermal expansion studies demonstrate positive thermal expansion coefficient along the crystallographic stacking axis, with signatures of magnetoelastic coupling by the onset of magnetic order for both $Fe_2P_2S_6$ and $Ni_2P_2S_6$ single crystals. We estimated the uniaxial pressure dependence of antiferromagnetic ordering temperature from heat capacity and thermal expansion.

MA 40.58 Thu 14:00 P2/EG

Unconventional Spin State Driven Spontaneous Magnetization in $RE_3Fe_3Sb_7$ — •S. Palazzese[1,2], F. Pabst[3], S. Chattopadhay[1], Sh. Yamamoto[1], T. Herrmannsdoerfer[1], D. Gorbunov[1], E. Weschke[4], O. Prokhnenko[4], H. Nojiri[5], T. Doert[3], B. Lake[4,6], J. Wosnitza[1,2], and M. Ruck[3] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörperund Materialphysik, Technische Universität Dresden (TUD), Germany — [3]Fakultät für Chemie und Lebensmittelchemie, TUD, Germany — [4]Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Berlin, Germany — [5]Institute for Materials Research, Tohoku University, Sendai, Japan — [6]Institut für Festkörperphysik, Technische Universität Berlin, Germany

Consolidating a microscopic understanding of magnetic properties is crucial for a rational design of magnetic materials with tailored characteristics. The interplay of 3d and 4f magnetism in rare-earth transition metal antimonides is an ideal platform to search for such complex behavior. Here we present a detailed magnetization and electrical-transport study of novel $RE_3Fe_3Sb_7$ compounds. $RE_3Fe_3Sb_7$ shows a an emergent spontanoeus magnetization in zero applied field and a kink in the temperature-dependent resistivity, indicating a symmetry breaking at the spin-reorientation transition (SRT). Our XMCD and additional neutron scattering results reveal an unusual antiparallel alignment of Pr and Fe magnetic moments.

MA 40.59 Thu 14:00 P2/EG

2D van-der Waals Heterostructures — •Burak Özer[1], Arthur Veyrat[1], Sebastian Selter[1], Saicharan Aswartham[1], Rudolf Schäfer[2], Ivan Soldatov[2], Bernd Büchner[1,3], and Burak Ozer[1] — [1]Leibniz IFW Dresden, Institute for Solid State Research, 01069 Dresden, Germany — [2]Helmholtzstr 20 — [3]Technische Universität Dresden, Faculty of Physics, 01062 Dresden, Germany

2D materials and their properties are being investigated since 2004 when researchers obtained the monolayer graphene and investigated its excellent electrical properties. To produce down-to-monolayer materials the mechanical exfoliation technique has been used since the very beginning. In 2013, researchers found a technique that allows to build a 3D structure from exfoliated 2D materials like LEGO blocks and control their physical properties, called van-der-Waals (vdW) stacking. Combining 2D materials for the discovery and characterization of new topological phases could pave the way for many opportunities for new and interesting fundamental aspects of physics, also for potential applications. This work shows how to exfoliate and encapsulate different materials, including graphene, hBN and Cr_2 Ge_2 Te_6 (T_c ~62 K) crystal, which is a paramagnetic at bulk; but recently researchers have found out at down-to-monolayer thicknesses, it showed ferromagnetic behavior. The magnetism of Cr_2 Ge_2 Te_6 has investigated at several thicknesses to observe their hysteresis curves by MOKE; to compare the difference between encapsulated with hBN and free-standing CGT behavior, we conducted the magnetic measurement for two different flakes.

MA 40.60 Thu 14:00 P2/EG

Strain control on band topology and surface states in antiferromagnetic EuCd2As2 — •Nayra Alvarez[1], Venkata Bharadwaj[1], Bennet Karetta[1], Rodrigo Jaeschke[1], Adrian Valadkhani[2], Libor Smejkal[1], and Jairo Sinova[1] — [1]Institut fur Physik, Johannes Gutenberg Universitat, Mainz, Germany — [2]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany

We study the effect of strain on EuCd2As2 and the effect on its topological features in different interlayer antiferromagnetic configurations [1]. Magnetic Anisotropy calculations indicate that the modulation of the lattice structure with strain can lead to a change in the direction of the magnetic moment changing the topology of the system [2,3]. We performed band structure calculations for the different strained configurations, applying three different kinds of stress along the x-y plane: volumetric, longitudinal, and shear. In addition, we analyse the surface states at different cleavage surfaces.

[1] J. Ma, H. Wang, S. Nie, et al., "Emergence of nontrivial low-energy Dirac fermions in antiferromagnetic EuCd2As2", Advanced Materials.

[2] G. Hua, S. Nie, et al., "Dirac semimetal in type-IV magnetic space groups", Physical Review B.

[3] E. Gati, S. L. Budko, et al., "Pressure-induced ferromagnetism in the topological semimetal EuCd2As2", Physical Review B.

MA 40.61 Thu 14:00 P2/EG

Strain control of band topology and surface states in antiferromagnetic EuCd2As2 — •Nayra Alvarez[1], Venkata Bharadwaj[1], Bennet Karetta[1], Rodrigo Jaeschke[1], Adrian Valadkhani[2], Libor Smejkal[1], Jairo Sinova[1], and Roser Valenti[2] — [1]Institut fur Physik, Johannes Gutenberg Universitat, Mainz, Germany — [2]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany

We study the effect of strain on EuCd2As2 and the effect on its topological features in different interlayer antiferromagnetic configurations [1]. Magnetic anisotropy calculations indicate that the modulation of the lattice structure with strain can lead to a change in the direction of the magnetic moment changing the topology of the system [2,3]. We performed band structure calculations for the different strained configurations. We consider three different kinds of stress along the x-y plane: volumetric, longitudinal, and shear. In addition, we analyse the surface states at different cleavage surfaces.

[1] J. Ma, H. Wang, S. Nie, et al., "Emergence of nontrivial low-energy Dirac fermions in antiferromagnetic EuCd2As2", Advanced Materials.

[2] G. Hua, S. Nie, et al., "Dirac semimetal in type-IV magnetic space groups", Physical Review B.

[3] E. Gati, S. L. Budko, et al., "Pressure-induced ferromagnetism in the topological semimetal EuCd2As2", Physical Review B.

MA 40.62 Thu 14:00 P2/EG

Influence of disorder and multi-magnon processes on the magnonic properties of ultrathin metallic ferromagnets — •Sebastian Paischer[1], Arthur Ernst[1], Igor Maznichenko[2], David Eilmsteiner[1], Khalil Zakeri[3], and Pawel Buczek[4] — [1]Johannes Kepler University, Linz, Austria — [2]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [3]Karlsruhe Intitute of Technology, Karlsruhe, Germany — [4]Hamburg University of Applied Sciences, Hamburg, Germany

Understanding the processes behind the excitation and relaxation of spin excitations in low-dimensional magnetic structures is one of the most intriguing research directions in solid-state physics. A detailed knowledge of the fundamental mechanisms involved in such processes is the key to understanding many different phenomena like ultrafast magnetization reversal. In this poster session we compare different magnon damping mechanisms in ultrathin metallic films. While the Landau-damping is the most dominant channel, we show that a significant contribution of the damping originates from substitutional disorder. Also the influence of multi-magnon processes on the magnonic properties of these materials will be discussed.

MA 40.63 Thu 14:00 P2/EG

Transverse magnetotransport in unconventional antiferromagnet Mn_5Si_3 — •Sebastian Beckert[1], Antonin Bad'ura[2], Miina Leiviskä[3], Eva Schmoranzerová[4], Ismaila Kounta[5], Dominik Kriegner[2], Andy Thomas[1,6], Libor Šmejkal[7], Jairo Sinova[7], Tomáš Jungwirth[2], Lisa Michez[5], Sebastian T. B. Goennenwein[8], Vincent Baltz[3], and Helena Reichlová[1,2] — [1]TU Dresden — [2]IoP ASCR Prague — [3]Spintec Grenoble — [4]Charles University Prague — [5]CINaM Marseille — [6]IFW Dresden — [7]JGU Mainz — [8]University of Konstanz

Traditional collinear antiferromagnets do not exhibit a spin polarization in the band structure. Therefore, the anomalous Hall and Nernst effect are forbidden in this materials. Recent theory developments predict a new class of magnetically ordered compensated materials with particular crystal and spin symmetries that break the time inversion symmetry in the reciprocal space [1,2]. One experimental demonstration are epitaxially grown Mn_5Si_3 films. In these samples with a (0001) film normal, we observe a robust anomalous Hall effect despite vanishing magnetization [3]. On this poster, we will discuss the magnetothermal transport properties of this compound in more detail and the symmetry of measured signals.

[1] L. Šmejkal et al., Sci. Adv. **6**, aaz8809 (2020).
[2] L. Šmejkal et al., Phys. Rev. X **12**, 031042 (2022).
[3] H. Reichlova et al., arXiv preprint arXiv:2012.15651 (2020).

MA 40.64 Thu 14:00 P2/EG

Magneto-transport measurements in altermagnetic RuO_2 and MnTe — •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], Jakub Železný[3], Philipp Ritzinger[3], Joseph Dufouleur[2], Louis Veyrat[2], Teresa Tschirner[2], Simon Moser[7], Libor Šmejkal[8], Tomas Jungwirth[3,9], Sebastian Tobias Benedikt Goennenwein[1,10], Andy Thomas[1,2], Dominik Kriegner[3], and Helena Reichlová[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]JKU Linz — [7]University of Wuerzbug — [8]JGU, Mainz — [9]University of Nottingham — [10]University of Konstanz

In altermagnets [1], spin polarization in both crystal-structure real space and electronic-structure momentum space alternates and, consequently, it enables effects that were believed to be exclusive to ferromagnets. Many of the predicted altermagnetic phenomena [2] await their experimental confirmation. Here, we present a magnetotransport characterization of two altermagnetic materials - semiconducting MnTe [3] and metallic RuO_2. We discuss which contributions to the measured transversal and longitudinal signals can be signatures of the unconventional altermagnetic phase.

[1] L. Šmejkal et al., Phys. Rev. X. 12.031042 (2022) [2] L. Šmejkal et al., Phys. Rev. X. 12.011028 (2022) [3] R. D. Gonzalez Betancourt et al., (2021) arXiv:2112.06805

MA 40.65 Thu 14:00 P2/EG

Tuning of magnetoelastic coupling with acoustic impedance matching techniques — •Johannes Weber[1,2], Manuel Müller[1,2], Stephan Geprägs[1], Rudolf Gross[1,2,3], Hans Huebl[1,2,3], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]TUM School of Natural Sciences, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Magnetoelastic coupling and the coherent emission of phonon modes generated by magnon Kittel modes have regained interest because of their potential applications in quantum devices [1]. So far primarily the ferrimagnetic insulator yttrium iron garnet (YIG) grown on single crystal substrates of the paramagnetic insulator gadolinium gallium garnet (GGG) has been used in experiments. However, as YIG requires epitaxial growth, the choice of material combinations is limited. Therefore we studied magnon-phonon coupling in acoustic resonators consisting of polycrystalline magnetic thin-films grown on silicon substrates, as this material platform would allow for the implementation of magnetoelastic coupling effects in existing CMOS-technology. In particular, we investigate whether a tuning of the magnetoelastic coupling between magnetic metal thin films and silicon substrate can be achieved by inserting an intermediated metallic layer, allowing for better acoustic impedance matching [2].

[1] K. An et al., Phys. Rev. X **12**, 011060, (2022).
[2] V. Rathod, Sensors, **20**, 4051, (2020).

MA 40.66 Thu 14:00 P2/EG

Towards shaping picosecond strain pulses via magnetostrictive transducers — Maximilian Mattern[1], Jan-Etienne Pudell[1,2,3], Karine Dumesnil[4], •Alexander von Reppert[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität 14476 Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, 12489 Berlin, Germany — [3]European XFEL, 22869 Schenefeld, Germany — [4]Institut Jean Lamour (UMR CNRS 7198), Université Lorraine, 54000 Nancy, France

Using time-resolved x-ray diffraction, we demonstrate the manipulation of the picosecond strain response of a metallic heterostructure consisting of a dysprosium (Dy) transducer and a niobium (Nb) detection layer by an external magnetic field. We utilize the first-order ferromagnetic-antiferromagnetic phase transition of the Dy layer, which provides an additional large contractive stress upon laser excitation compared to its zero-field response. This enhances the laser-induced contraction of the transducer and changes the shape of the picosecond strain pulses driven in Dy and detected within the buried Nb layer. Based on our experiment with rare-earth metals we discuss required properties for functional transducers, which may allow for novel field-control of the emitted picosecond strain pulses.

MA 41: Focus Session: Altermagnetism: Transport, Optics, Excitations

While antiferromagnetic spintronics is an established research field, key spintronic functionalities such as giant/tunneling magnetoresistance (GMR/TMR), have remained elusive in compensated magnetic systems. This paradigm could change in the light of the recent theoretical discovery of a new class of magnetic materials so called altermagnets which feature alternating spin polarizations in both crystal-structure real space and electronic-structure momentum space. Despite the vanishing net magnetization and antiparallel spin arrangement, altermagnets were predicted to exhibit a robust anomalous Hall effect and GMR and spin transfer torque phenomena. The predictions have been already supported by initial experiments. The goal of this focus session is to introduce the concept of altermagnetism to the broad research community, to present the first experimental works and stimulate future research directions. Here, altermagnets are predicted to have a broad impact beyond spin-electronics in fields ranging from magneto-transport, ultra-fast photo-magnetism to superconductivity and magnetic topological matter. The Focus Session is organized by Dr. Matthias Althammer (Walther-Meißner-Institut, Garching), Prof. Sebastian Goennenwein (Uni Konstanz) and Dr. Andy Thomas (IFW Dresden).

Time: Thursday 15:00–18:00 Location: HSZ 02

Invited Talk MA 41.1 Thu 15:00 HSZ 02

Altermagnetism and spin symmetries — •Libor Šmejkal — Johannes Gutenberg Universitat Mainz, Germany — Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic

Different phases of matter can be distinguished by symmetries and order parameters. In this talk, we will discuss the classification of magnetically ordered crystals according to recently studied spin symmetries [1]. Spin symmetries consider pairs of operations in spin and crystal space and remarkably reveal an unconventional magnetic class. This unconventional class, called altermagnetism, is sharply distinct from ferromagnets and antiferromagnets. It is characterized by an unconventional alternating spin order in electronic momentum space that breaks time-reversal symmetry and is spin compensated and anisotropic [1,2]. We show that these properties can arise from ordered and anisotropic spin densities and crystal fields, as described for a typical Ruthenium Dioxide altermagnet [1-4]. Finally, we show that altermagnetism provides a unifying explanation for the recently predicted and experimentally observed unconventional anomalous Hall effects in collinear systems without magnetisation [2,3,5 and references therein].

[1] Šmejkal, L., Sinova, J., and Jungwirth, T., Phys. Rev. X 12, 031042 (2022), [2] Šmejkal, L. et al., Science Advances 6, eaaz8809 (2020) [3] Feng, Z., et al. Nature Electron. 5, 735-743 (2022) [4] Šmejkal, L. et al., Phys. Rev. X 12, 011028 (2022) [5] Mazin, I.I et al., PNAS 118 (42) e2108924118 (2021)

Invited Talk MA 41.2 Thu 15:30 HSZ 02

Spontaneous Hall effect in Mn5Si3 altermagnet — •H. Reichlova[1,2], R. Lopes Seeger[3], R. González-Hernández[4], I. Kouta[6], R. Schlitz[1], D. Kriegner[2], P. Ritzinger[2], M. Lammel[9], M. Leiviska[3], V. Petricek[2], E. Schmoranzerova[7], A. Badura[2], A. Thomas[1,8], V. Baltz[3], L. Michez[6], J. Sinova[5,2], S.T.B. Goennenwein[9], T. Jungwirth[2,10], and L. Smejkal[5,2] — [1]IFMP, Technische Universität Dresden — [2]Institute of Physics CAS, Czech Republic — [3]CNRS, CEA, Grenoble, France — [4]Universidad del Norte, Barranquilla, Colombia — [5]Johannes Gutenberg Universität Mainz — [6]CINaM, Marseille, France — [7]MFF Charles University, Praha, Czech Republic — [8]IFW Dresden — [9]Universität Konstanz — [10]University of Nottingham, United Kingdom

The family of materials that can exhibit spontaneous Hall effect has been significantly expanded by discovery of altermagnets with opposite spin sublattices coupled by crystallographic rotations [1]

I present our observations of the spontaneous Hall effect in an altermagnetic candidate - Mn5Si3 epilayers [2]. Epitaxial constraints stabilize a hexagonal unit cell in the magnetic state distinct from previously described phases in bulk crystals and we observe a sizable spontaneous Hall conductivity. The signal can be explained by an unprecedented altermagnetic band structure with time-reversal symmetry breaking spin-polarized valleys.

[1] Smejkal et al. Science Advances 6, 23 (2020) [2] Reichlova H. et al., arXiv:2012.15651

MA 41.3 Thu 16:00 HSZ 02

Spin-split collinear antiferromagnets: a large-scale ab-initio study — •Yaqian Guo[1], Hui Liu[1,2], Oleg Janson[1], Ion 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, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, Germany — [3]Centro Atómico Bariloche and Instituto Balseiro, Argentina — [4]Instituto de Nanociencia y Nanotecnología CNEA-CONICET, Argentina

It was recently discovered that, depending on their symmetries, collinear antiferromagnets can break the spin degeneracy in momentum space, even in the absence of spin-orbit coupling. Such systems are signalled by the emergence of a spin-momentum texture set mainly by the crystal and magnetic structure, relativistic effects playing a secondary role. Here we consider all collinear q=0 antiferromagnetic compounds in the MAGNDATA database allowing for spin-split bands. Based on density-functional calculations for the experimentally reported crystal and magnetic structures, we study more than sixty compounds and introduce numerical measures for the average momentum-space spin splitting. We highlight some compounds that are of particular interest, either due to a relatively large spin splitting, such as CoF_2 and $FeSO_4F$, or because of their low-energy electronic structure. The latter include $LiFe_2F_6$, which hosts nearly flat spin-split bands next to the Fermi energy, as well as RuO_2, $CrNb_4S_8$, and CrSb, which are metals.

MA 41.4 Thu 16:15 HSZ 02

Giant magnetoresistance effects in altermagnets — •Anna Birk Hellenes[1], Rafael González-Hernández[2], Jairo Sinova[1,3], Tomas Jungwirth[3,4], and Libor Šmejkal[1,3] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Universidad del Norte, Barranquilla, Colombia — [3]Czech Academy of Sciences, Prague, Czech Republic — [4]University of Nottingham, United Kingdom

Commercial spintronics devices using magnetoresistance effects rely on spin currents in ferromagnets, generated by a time-reversal symmetry broken band structure. To realise a counterpart effect with all-antiferromagnetic electrodes has remained experimentally elusive, as the combined time-reversal symmetry with translation or inversion in antiferromagnets prohibits nonrelativistic spin polarisation. Recently, a third fundamental magnetic order was discovered, which exhibits exclusively different spin symmetries from ferromagnets and antiferromagnets[1]. In these altermagnets, the spin polarisation forms d,g, or i-wave compensated spin order in momentum space which breaks time-reversal symmetry. Hence, altermagnetism provides a unifying explanation for our recently predicted giant TMR and GMR effects[2,3]. In the present contribution, we describe the symmetry requirements that lead to distinct spin polarisations such as the d-wave type, and illustrate the GMR and TMR mechanism with tight-binding models and in the candidate materials RuO_2 and Mn_5Si_3. [1] L. Šmejkal et al., Phys. Rev. X 12, 031042, 2022. [2] L. Šmejkal, A. B. Hellenes et al., Phys. Rev. X 12, 011028, 2022. [3] H. Reichlova et al., arXiv:2012.15651v2.

Invited Talk MA 41.5 Thu 16:30 HSZ 02

Generation of tilted spin-current by the collinear antiferromagnet RuO2 — •Arnab Bose — Johannes Gutenberg Universität, Mainz, Germany

Recently a new type of magnetic material is theoretically proposed, referred to as *altermagnet* which is a collinear antiferromagnet in real space although hosting the spin-split bands in the momentum space that allows it to exhibit the properties of ferromagnet depending upon the direction of the current flow with respect to the crystal axis [1,2]. We report the first experimental evidence of strongly crystal axis-dependent unconventional transverse spin-current generation by the altermagnet RuO2 [3] arising from the novel spin-split bands as theoretically predicted [1]. This unconventional tilted spin-current is the key to the implementation of high-density nonvolatile magnetic memories.

[1] R. González-Hernández et. al. Phys. Rev. Lett. 126, 127701 (2021) [2] L. Šmejkal et. al. arXiv: 2204.10844 (2022) [3] A. Bose et. al. Nature Electronics 5, 267 (2022).

Invited Talk MA 41.6 Thu 17:00 HSZ 02

First-principles studies on the anomalous transport properties of ferromagnets, antiferromagnets, and altermagnets — •Wanxiang Feng — School of Physics, Beijing Institute of Technology, Beijing 100081, China

Magnetic topological semimetals bring new vitality to the ideas evolving around the next generation of dissipationless spintronic devices benefiting from their exotic anomalous and spin transport properties. I shall first show that ferromagnetic MF_3 (M = Pd, Mn) are high-quality nodal chain spin-gapless topological semimetals with 100% spin-polarized transport properties. The dominant intrinsic origin is found to originate entirely from the gapped nodal chains without the entanglement of any other trivial bands. The side-jump mechanism is predicted to be negligibly small, but the skew scattering enhances the intrinsic Hall and Nernst signals significantly. Second, I shall present the spin-chirality-dependent anomalous Hall and Nernst effects in coplanar noncollinear antiferromagnets Mn_3XN (X = Ga, Zn, Ag, and Ni) as well as the topological magneto-optical effects and their quantization in noncoplanar antiferromagnets γ-Fe_xMn_{1-x} and $K_{0.5}RhO_2$. Beyond ferromagnetism and antiferromagnetism, altermagnetism is recently discovered to be the third essential magnetic phase. Room-temperature metallic RuO_2 is a typical altermagnet, in which the rearrangement of nonmagnetic atoms induces crystal chirality playing a critical role in anomalous transport properties. Finally, I will discuss the crystal-chirality-dependent anomalous Nernst, anomalous thermal Hall, and magneto-optical effects in RuO_2.

Invited Talk MA 41.7 Thu 17:30 HSZ 02

Insight into chemical and magnetotransport properties of epitaxial α-Fe2O3/Pt bilayers — •Anna Kozioł-Rachwał[1], Natalia Kwiatek[2], Witold Skowroński[3], Krzysztof Grochot[3], Jarosław Kanak[3], Ewa Madej[2], Kinga Freindl[2], Józef Korecki[2], and Nika Spiridis[2] — [1]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Mickiewicza 30, 30-059 Kraków, Poland — [2]Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, 30-239 Kraków, Poland — [3]Institute of Electronics, AGH University of Science and Technology, Mickiewicza 30, 30-059 Kraków, Poland

Recently a spin Hall magnetoresistance (SMR) was presented for Pt/α-Fe2O3(hematite) bilayer.[1],[2] In our studies we investigated the chemical structure and SMR in epitaxial α-Fe2O3(0001)/Pt(111) bilayers with hematite layers grown by molecular beam epitaxy on a MgO(111) substrate.[3] We observed a sign change of the SMR from positive to negative when the thickness of the hematite increased from 6 to 15 nm. For α-Fe2O3(15 nm)/Pt, we demonstrated room-temperature switching of the Néel order with rectangular, nondecaying switching characteristics. Such structures open the way to extending magnetotransport studies to more complex systems with double asymmetric metal/hematite/Pt interfaces. [1] J. Fischer et al. Phys. Rev. Applied 13, 014019 (2020). [2] Y. Cheng et al. Phys. Rev. Lett. 124, 027202 (2020). [3] A. Kozioł-Rachwał et al., Phys. Rev. B 106, 104419 (2022).

MA 42: Caloric Effects in Ferromagnetic Materials

Time: Thursday 15:00–17:45 Location: HSZ 04

MA 42.1 Thu 15:00 HSZ 04

Exploring rare earth Laves phases for magnetocaloric hydrogen liquefaction — •Bruno Weise[1], Marvin Hofmann[1,2], Lukas Beyer[1,3], and Tino Gottschall[4] — [1]Leibniz IFW, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]TU Bergakademie Freiberg, Freiberg, Germany — [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The replacement of fossil fuels with renewable energies is an integral part of fighting the global climate crisis. Green hydrogen, produced with renewable energies, is one of the most promising energy sources. The unsurpassed high storage density of liquid hydrogen offers great advantages, especially on long transport routes. By magnetocaloric cooling the efficiency of the energy-intensive liquefaction of hydrogen will be increased. RE-X_2 Laves phases, are ideal for low temperature hydrogen liquefaction in the temperature range between 77 and 20 K.

By substitution of individual elements in the RE-X_2 Laves phases the transition temperature can be manipulated, while maintaining the magnetocaloric performance. A substitution series of $DyNi_{2-x}Al_x$ was prepared by arc melting and studied by structural, magnetic and thermodynamic characterization methods. The investigated alloy series $DyNi_{2-x}Al_x$ shows a nonlinear substitution dependency of the Curie Temperature and adiabatic temperature change. In pulsed field measurements a temperature of up to 17 K for 10 T magnetic field pulse was measured. In the present contribution we will evaluate the suitability of the $DyNi_{2-x}Al_x$ rare earth Laves phases for magnetocaloric hydrogen liquefaction.

MA 42.2 Thu 15:15 HSZ 04

Lattice contribution to entropy change at first-order phase transition in Laves phase $DyCo_2$ — •Johanna Lill[1], Benedikt Eggert[1], Jiyong Zhao[2], Benedikt Beckmann[3], Barbara Lavina[2], Michael Hu[2], Konstantin Skokov[3], Tom Toellner[2], Esen E. Alp[2], Katharina Ollefs[1], Oliver Gutfleisch[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]APS, Lemont, Illinois - US — [3]TU Darmstadt, Darmstadt, Germany

Laves phases are promising candidates for facilitating liquefaction, applying the magnetocaloric effect. The Laves phase of $DyCo_2$ undergoes a first-order phase transition around 140 K from a ferromagnetic (at low temperatures) to a disordered magnetic phase (at higher temperatures). The magnetic phase transition accompanies a structural change from cubic to tetragonal symmetry also resulting in a volume discontinuity. The magnetocaloric effect is a change in entropy along a phase transition, which in an adiabatically performed cooling cycle can lead to the desired cooling effect. This effect can be characterized by the amount of entropy change at the first-order phase transition. For magnetocaloric applications and improvement of reversible magnetocaloric effect it is therefore essential to understand the contributions of different subsystems to the overall entropy change. In this presentation, we show experimental data that resolves the Dy-partial lattice entropy of the $DyCo_2$ Laves phase along the first-order phase transition utilizing nuclear resonant inelastic x-ray scattering. We acknowledge financial support from DFG through TRR270 HoMMage.

MA 42.3 Thu 15:30 HSZ 04

Designing a light rare-earth-based material system for magnetocaloric hydrogen liquefaction — •Wei Liu[1], Franziska Scheibel[1], Tino Gottschall[2], Eduard Bykov[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt — [2]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany

Hydrogen will play a key role in 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 a "game-changer". However, the high criticalities of the heavy rare-earth elements put a question on the usage of the heavy rare-earth-based magnetocaloric materials in industrial scales, although they show large magnetic entropy and adiabatic temperature changes.[3] On the other hand, the relatively high abundances of light rare-earth elements make their alloys appealing for industrial-scale applications. In this work, based on the analysis of mean-field theory, we propose a method of designing a light rare-earth-based magnetocaloric material system with Ce, Pr, and Nd for hydrogen liquefaction.

MA 42.4 Thu 15:45 HSZ 04

Multicaloric effect and exploited hysteresis in the Heusler alloy Ni-Mn-Sn-Fe-Co — •T. Niehoff[1,2], T. Gottschall[1], C. Salazar Mejia[1], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik TUD, Dresden, Germany

Today's research on commercial magnetocaloric cooling focuses on reducing the hysteresis of materials with first-order phase transitions. In contrast, this work exploits the width of hystereses to achieve more effective cooling performance with a combination of multiple caloric effects and investigates the coupling between the magnetocaloric and elastocaloric effects. The hysteresis is finetuned by substituting the proper amount of Fe and Co in the Heusler alloy Ni-Sn. To study the material, simultaneous magnetization, strain, and adiabatic temperature changes are compared at a range of different initial temperatures and various uniaxial loads in pulsed magnetic fields up to 50 T.

MA 42.5 Thu 16:00 HSZ 04

Effect of Pt substitution on the reversibility of the magnetocaloric effect in Ni-Pt-Mn-In Heusler alloys — •Parul Devi[1], C. Salazar-Mejia[1], S. Singh[2], and J. Wosnitza[1,3] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]School of Materials Science and Technology, Indian Institute of Technology (BHU), Varanasi, India — [3]Institut für Festkörper –und Materialphysik, TU Dresden, Germany

Among different magnetic shape memory Heusler alloys, $Ni_2Mn_{1.4}In_{0.6}$ is one of the most studied system for multiple caloric effects. However, obstacles such as the low-temperature martensitic transition and large thermal hysteresis hinder its technological applications motivating the search for novel materials showing better mechanical properties as well as higher martensitic transition temperature [1 and references within]. Here, we will present the experimental results such as the crystal structure determined by x-ray diffraction, magnetization in static magnetic fields, and the adiabatic temperature change in pulsed magnetic field of quaternary $Ni_{2-x}Pt_xMn_{1.4}In_{0.6}$ ($0 \leq x \leq 0.2$) shape memory alloys. The substitution of Pt affects the geometric compatibility condition without changing the space group symmetry of the austenite and the martensite phase. Around the martensitic transition temperature, a large value of ΔT_{ad} was found in pulsed magnetic fields due to the compatibility of austenite and martensite phase.

[1] K. K. Dubey et al., J. Magn. Magn. Mat. **507**, 166818 (2020).

15 min. break

MA 42.6 Thu 16:30 HSZ 04

Simultaneous measurements of adiabatic temperature change and magnetization in Fe-Ni-Rh. — •Catalina Salazar-Mejia[1], Alisa M. Chirkova[2], Shingo Yamamoto[1], Jochen Wosnitza[1,3], and Tino Gottschall[1] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]FH Bielefeld, University of Applied Sciences, Germany — [3]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

We have performed simultaneous measurements of the magnetization and the adiabatic temperature change in an $Fe_{49}Ni_1Rh_{50}$ alloy. The material exhibits an antiferromagnetic (AFM) to ferromagnetic (FM) transition at $T_{tr} \approx 326$ K. Specifically, we have studied the field-induced metamagnetic AFM-FM transition at temperatures well below T_{tr} in high pulsed magnetic fields. Due to the large magnetocaloric effect (MCE) of the material, magnetization measurements in pulsed magnetic fields are not isothermal. Recording the temperature of the sample during the measurement allows not only to characterized the MCE of the material, but to precisely determine the magnetic phase diagram.

MA 42.7 Thu 16:45 HSZ 04

The local magnetic and geometric structure in Mn-doped La(Fe,Si)$_{13}$ — •Benedikt Eggert[1], Johanna Lill[1], Konstantin Skokov[2], Cynthia Pillich[1], Alexandra Terwey[1], Fabrice Wilhelm[3], Mauro Rovezzi[3], Andrei Rogalev[3], 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 — [3]European Synchrotron Radiation Facility

Magnetic cooling has the potential to replace conventional gas compression refrigeration. Materials such as La(Fe,Si)$_{13}$ exhibit a sizeable first-order magnetocaloric effect. For Mn-H doped La(Fe,Si)$_{13}$, it is possible to tailor the phase transition towards room temperature while maintaining first-order character. In this contribution, we discuss the effects of Mn-doping in La(Fe,Si)$_{13}$ on the magnetic moments and the local environment by means of X-ray magnetic circular dichroism and extended X-ray absorption spectroscopy in the hard X-ray regime. Spectroscopic results indicate a reduction of the Fe magnetic moment and an increased structural disorder around the La site, which is not identified for the Fe sites. Furthermore, first-principles calculations reveal energetically unfavourable Mn-Si bonds that lead to a broad distribution of La-Si bond lengths that explain the experimentally observed structural disorder. We acknowledge the financial support through the Deutsche Forschungsgemeinschaft within the framework of the CRC/TRR 270 HoMMage and thank the ESRF for allocating beamtimes at ID12 and BM30.

MA 42.8 Thu 17:00 HSZ 04

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]Institut für Festkörper- und Materialphysik Technische Universität Dresden, Dresden, Germany

The La(Fe,Si)$_{13}$ family is a very 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 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 $z = 0 \ldots 0.4$, $y = 0 \ldots 0.04$ and determined the adiabatic temperature change in pulsed magnetic fields. For selected samples, we calculated the magnetic entropy change using isothermal magnetization measurements.

MA 42.9 Thu 17:15 HSZ 04

Rapid bulk sintering and magnetocaloric performance of polycrystalline $Fe_2Al_{1.15-x}B_2Ge_xGa_x$ (x=0, 0.05) MAB phases — •Benedikt Beckmann[1], Tarek El-Melegy[2], David Koch[1], Ulf Wiedwald[3], Michael Farle[3], Fernando Maccari[1], Joshua Snyder[2], Konstantin Skokov[1], Michel Barsoum[2], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Institute of Materials Science, Darmstadt, Germany — [2]Drexel University, Department of Materials Science & Engineering, Philadelphia, PA, USA — [3]University of Duisburg Essen, CENIDE, Duisburg, Germany

Reactive single-step hot-pressing at 1473 K and 36 MPa for 4 h produces dense, bulk, near single-phase, low-cost and low-criticality $Fe_2Al_{1.15}B_2$ and $Fe_2Al_{1.1}B_2Ge_{0.05}Ga_{0.05}$ MAB samples, showing a second-order magnetic phase transition with favorable magnetocaloric properties at room temperature. The maximum isothermal entropy change Δs_T of hot-pressed $Fe_2Al_{1.15}B_2$ in magnetic field changes of 2 and 5 T amounts to 2.5 and 5 J(kgK)$^{-1}$ at 287.5 K and increases by Ge and Ga addition to 3.1 and 6.2 J(kgK)$^{-1}$ at 306.5 K, respectively. The directly measured maximum adiabatic temperature change ΔT_{ad} in magnetic field changes of 1.93 T is improved by the alloy design from 0.9 to 1.1 K. Our criticality assessment shows that hot-pressed Fe-based MAB phases provide a promising compromise between material and processing cost, criticality and magnetocaloric performance around room temperature.

We acknowledge financial support from DFG (CRC/TRR 270, Project-ID 405553726).

MA 42.10 Thu 17:30 HSZ 04

Effect of Pt substitution on the reversibility of the magnetocaloric effect in Ni-Pt-Mn-In Heusler alloys — •Parul Devi[1], C. Salazar-Mejia[1], S. Singh[2], and J. Wosnitza[1,3] — [1]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]School of Materials Science and Technology, Indian Institute of Technology (BHU), Varanasi, India — [3]Institut für Festkörper –und Materialphysik, TU Dresden, Germany

Among different magnetic shape memory Heusler alloys,

$Ni_2Mn_{1.4}In_{0.6}$ is one of the most studied system for multiple caloric effects. However, obstacles such as the low-temperature martensitic transition and large thermal hysteresis hinder its technological applications motivating the search for novel materials showing better mechanical properties as well as higher martensitic transition temperature [1 and references within]. Here, we will present the experimental results such as the crystal structure determined by x-ray diffraction, magnetization in static magnetic fields, and the adiabatic temperature change in pulsed magnetic field of quaternary $Ni_{2-x}Pt_xMn_{1.4}In_{0.6}$ ($0 \leq x \leq 0.2$) shape memory alloys. The substitution of Pt affects the geometric compatibility condition without changing the space group symmetry of the austenite and the martensite phase. Around the martensitic transition temperature, a large value of ΔT_{ad} was found in pulsed magnetic fields due to the compatibility of austenite and martensite phase.

[1] K. K. Dubey et al., J. Magn. Magn. Mater. **507**, 166818 (2020).

MA 43: Magnetic Imaging Techniques II

Time: Thursday 15:00–16:45 Location: HSZ 401

MA 43.1 Thu 15:00 HSZ 401

Three-dimensional tomographic imaging of the magneti- zation vector field using Fourier transform holography — •Marisel Di Pietro Martínez[1,2], Alexis Wartelle[1,3], Carlos Herrero Martínez[1], Farid Fettar[4], Jean-François Motte[4], Claire Donnelly[2], Luke Turnbull[5], Feodor Ogrin[5], Gerrit van der Laan[6], Horia Popescu[7], Nicolas Jaouen[7], Flora Yakhou-Harris[3], and Guillaume Beutier[1] — [1]UGA, CNRS, G-INP, SIMaP, Grenoble, France — [2]MPI-CPfS, Dresden, German — [3]ESRF, Grenoble, France — [4]UGA, CNRS, G-INP, Institut Néel, Grenoble, France — [5]School of Phys. and Engineering, University of Exeter, Exeter, UK — [6]Diamond Light Source, Didcot OX11 0DE, UK — [7]Synchrotron SOLEIL, Gif-sur-Yvette, France

Three-dimensional magnetic textures have recently attracted increasing interest both from a fundamental and a technological point of view. This emergent field of research comes with the need of new characterization techniques, specifically tomographic imaging. Here, we present a new tomographic technique based on Fourier transform holography, a lensless imaging technique that uses a known reference in the sample to retrieve the object of interest from its diffraction pattern in one single step of calculation. We obtain a 3D vectorial image of a 850nm-thick extended Fe/Gd multilayer in a 5000nm-diameter field of view with a resolution of 100nm, that reveals worm-like domains with magnetization pointing mostly out of plane near the surface of the sample but that falls in-plane near the substrate. As an outlook, this technique will enable a 3D study on the response to an external magnetic field.

MA 43.2 Thu 15:15 HSZ 401

Soft X-ray ptychography of micrometer thick samples — •Jeffrey N. Neethirajan[1], Benedikt Daurer[2], Ales Hrabec[3,4], Majid Kazemian[2], Marisel Di Pietro Martínez[1], Burkhard Kaulich[2], and Claire Donnelly[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Diamond Light Source, Harwell Science and Innovation Campus, Didcot, United Kingdom — [3]Laboratory for Mesoscopic Systems, Department of Materials, ETH Zurich, Zurich, Switzerland — [4]Laboratory for Multiscale Materials Experiments, Paul Scherrer Institute, Switzerland

Magnetism at the nanoscale offers a playground to study topology in real space. Although topological spin textures have so far been mainly studied in 2D, there is a growing interest in 3D topological spin textures. Recently, 3D imaging of extended systems with hard X-rays has revealed topological singularities called Bloch points and spin structures called vortex rings with nanoscale spatial resolution. However, the imaging of extended systems with hard X-rays is limited by the weak XMCD signals observed in this regime and restricted currently to a few rare-earths. In contrast, soft X-rays offer a stronger XMCD signal but limited to imaging samples that are 200-300 nm thick. Here we demonstrate the imaging of micrometer thick samples using soft X-ray ptychography - accessing a thickness regime previously impractical with conventional soft X-ray imaging techniques. This result is a step forward in realizing 3D imaging of extended systems with soft X-rays which offers a strong XMCD signal and the possibility to image exotic systems hosting topological textures.

MA 43.3 Thu 15:30 HSZ 401

Soft X-ray Ptychography of Bismuth Ferrite Nanoplates — •Tim A. Butcher[1], Manuel Langer[1], Simone Finizio[1], Lars Heller[1], Mirko Holler[1], Michal Jambor[2], Elisabeth Müller[3], Ashna Bajpai[4,5], Carlos A. F. Vaz[1], Armin Kleibert[1], and Jörg Raabe[1] — [1]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]Institute of Physics of Materials, Czech Academy of Sciences, Žižkova 22, 61600 Brno, Czech Republic — [3]Electron Microscopy Facility, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Department of Physics, Indian Institute of Science Education and Research, Pune 411008, India — [5]Centre for Energy Science, Indian Institute of Science Education and Research, Pune 411008, India

Soft x-ray ptychography is a scanning coherent diffractive imaging technique with spatial resolutions in the order of 10 nm, which relies on collecting diffraction patterns from overlapping illumination spots of the sample. The magnetic and ferroelectric structure of multiferroic bismuth ferrite nanoplates was studied with a new soft x-ray ptychography endstation at the Swiss Light Source. In particular, we demonstrate that the technique is able to resolve the antiferromagnetic spin cycloid and can yield the chirality in bismuth ferrite.

MA 43.4 Thu 15:45 HSZ 401

Direct imaging of nanoscale field-driven domain wall oscillations in Landau structures — •Balram Singh[1], Rachappa Ravishankar[1], Jorge A. Otálora[2], Ivan Soldatov[1], Rudolf Schäfer[1], Daniil Karnaushenko[3], Volker Neu[1], and Oliver G. Schmidt[3] — [1]Institute for Integrative Nanosciences, Leibniz IFW Dresden, 01069 Dresden, Germany — [2]Departamento de Física, Universidad Católica del Norte, Avenida Angamos 0610, Casilla 1280, Antofagasta, Chile — [3]Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, 09126 Chemnitz, Germany.

Linear oscillatory motion of domain walls (DWs) in the kHz and MHz regime is crucial when realizing precise magnetic field sensors such as giant magnetoimpedance devices. Here, we report an imaging approach to investigate such DW dynamics with nanoscale spatial resolution employing conventional table-top microscopy techniques. Time-averaged magnetic force microscopy and Kerr imaging methods are applied to quantify the DW oscillations in Permalloy rectangular structures with Landau domain configuration and are complemented by numeric micromagnetic simulations. We study the oscillation amplitude as a function of external magnetic field strength, frequency, magnetic structure size, thickness, and anisotropy and understand the excited DW behavior as a forced damped harmonic oscillator with restoring force being influenced by the geometry, thickness, and anisotropy of the Permalloy structure.

MA 43.5 Thu 16:00 HSZ 401

Tailoring magnetic switching via topology in nanoimprinted networks of Pt/Co/Pt caps on flexible membranes — •Jose A. Fernandez-Roldan[1], Rui Xu[1], Oleksii Volkov[1], Oleksandr Pylypovskyi[1], Ivan Soldatov[2], Andreas Worbs[1], Rene Hübner[1], Rudolf Schäfer[2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Leibniz IFW, Dresden, Germany

Perpendicular magnetic bit media consist of regular rigid nanostructured networks where data is stored in decoupled nanostructures. Flexible magnetic nanoelectronic devices rely on curvature-induced effects that introduce topological patterning [1]. We prepared arrays of magnetic bits with a size of 400 nm arranged in close-packed square and hexagonal arrays of Pt/Co/Pt cap-like structures on PDMS elastic membranes by means of nanoprinting and Al anodization. The magnetization reversal process indicates a magnetically decoupled switching process in the individual caps of the square array in contrast to the hexagonal array. Here we propose a method to evaluate this coupling by means of analysis of a series of field-dependent MOKE images. The results indicate that the magnetic coupling between the caps can be

quantitatively characterized in terms of a fractal dimension. Overall, these results suggest that the magnetization switching in densely-packed networks can be tailored via topology.

References: [1] D. Makarov et al., Adv. Mater. 34, 2101758 (2022)

MA 43.6 Thu 16:15 HSZ 401

Coherent Correlation Imaging for resolving fluctuating states of matter — •Christopher Klose[1], Felix Buettner[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. Guenther[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 Universitaet 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 43.7 Thu 16:30 HSZ 401

Origin of helicity-dependent photoconductivity in magnetic and nonmagnetic wires — •Atul Pandey[1,2], Rouven Dreyer[1], Palvan Seyidov[1], Chris Koerner[1], Saban Tirpanci[1], Binoy K. Hazra[2], Stuart Parkin[2], and Georg Woltersdorf[1,2] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

We study the opto-electric response in metallic wire structures. The aim is to understand the origin of helicity-dependent photoconductivity. For nonmagnetic metals this effect is generally believed to probe spin polarization. Using magnetic wires we show that this method enables background free imaging of spin textures. Analyzing the physical origin we find that the circular dichroism slightly modulates the absorption. The corresponding thermal modulation explains the measured electrical signals. We apply this result to examine the spin Hall effect induced spin accumulation in heavy metals. Here, we show that previously reported results in nonmagnetic wires are well reproducible, but not related to the spin polarization.

A. Pandey et al., Phys. Rev. B 106, 174420 (2022)

MA 44: Frustrated Magnets II

Time: Thursday 15:00–17:30 Location: HSZ 403

MA 44.1 Thu 15:00 HSZ 403

Magnetic Force Microscopy Investigations of the Kagome Spin Ice Host HoAgGe — •Tsuei-Shin Wu[1], Subhajit Roychowdhury[2], Samuel D. Seddon[1], Peter Milde[1], Claudia Felser[2], and Lukas M. Eng[1,3] — [1]Institute of Applied Physics, Technische Universität Dresden, Dresden, Germany — [2]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [3]Dresden-Würzburg Cluster of Excellence * Complexity and Topology in Quantum Matter (ct.qmat), TU Dresden, 01062 Dresden, Germany

The recent discovery of the quasi-2D spin ice on a Kagome lattice in HoAgGe [1] has highlighted this material system as the perfect environment in order to explore emerging questions and to clarify ongoing discussions regarding 2D spin ices within the scientific community. The presence of several high-order magnetization plateaus implies the possible existence of quantum magnetic states and/or non-collinear spin textures that may originate from quantum or thermal fluctuations [2]. Peaks in the topological Hall effect, which correlate with these magnetization plateaus, also potentially imply the presence of exotic spin textures - or at the very least non-collinear spin textures, which low-temperature (LT) Magnetic Force Microscopy (MFM) is perfectly placed to uncover. Here we present LT-MFM results when investigating the magnetic textures and their behaviors in HoAgGe samples under magnetic fields applied along the relevant crystallographic Kagome lattice directions.

Reference [1] Zhao et al., Science 367, 1218 (2020). [2] Baran et al., Journal of Alloys and Compounds 281, 92 (1998).

MA 44.2 Thu 15:15 HSZ 403

Coexistence of antiferromagnetism and ferrimagnetism in adjacent honeycomb layers — •Dávid Szaller[1], Lilian Prodan[2,3], Korbinian Geirhos[2], Viorel Felea[2,3,4], Yurii Skourski[4], Denis Gorbunov[4], Tobias Förster[4], Toni Helm[4], Toshihiro Nomura[4,5], Atsuhiko Miyata[4], Sergei Zherlitsyn[4], Jochen Wosnitza[4,6], Alexander A. Tsirlin[2], Vladimir Tsurkan[2,3], and Istvan Kezsmarki[2] — [1]Tu Wien — [2]University of Augsburg — [3]Institute of Applied Physics, R. Moldova — [4]Hochfeld-Magnetlabor Dresden — [5]University of Tokyo, Kashiwa — [6]TU Dresden

Ferro/ferri- and antiferromagnetic orders are typically exclusive in nature, thus, their co-existence in atomic-scale proximity is expected only in heterostructures. Breaking this paradigm we report the observation of a new, atomic-scale hybrid spin state. This ordering is stabilized in three-dimensional crystals of the polar antiferromagnet $Co_2Mo_3O_8$ by magnetic fields applied perpendicular to the *Co* honeycomb layers and possesses a spontaneous in-plane ferromagnetic moment. Our microscopic spin model, capturing the observed field dependence of the longitudinal and transverse magnetization as well as the magnetoelectric/elastic properties, reveals that this novel spin state is composed of an alternating stacking of antiferromagnetic and ferrimagnetic honeycomb layers. We show that the proper balance of magnetic interactions can extend the stability range of this hybrid phase down to zero magnetic field. The layer-by-layer stacking of distinct spin orders via suitable combinations of microscopic interactions opens a new dimension toward the nanoscale engineering of magnetic states.

MA 44.3 Thu 15:30 HSZ 403

Coupled frustrated ferromagnetic and antiferromagnetic quantum spin chains in the quasi-one-dimensional mineral antlerite, $Cu_3SO_4(OH)_4$ — A.A. Kulbakov[1], D.Y. Kononenko[2], S. Nishimoto[2,3], Q. Stahl[1], A. Mannathanath Chakkingal[1], M. Feig[4], R. Gumeniuk[4], Y. Skourski[5], L. Bhaskaran[5], S.A. Zvyagin[5], J.P. Embs[6], I. Puente-Orench[7,8], A. Wildes[8], J. Geck[1,9], O. Janson[2], D.S. Inosov[1,9], and •D.C. Peets[1] — [1]IFMP, TU Dresden — [2]Leibniz IFW-Dresden — [3]ITP, TU Dresden — [4]IEP, TU Bergakademie Freiberg — [5]HLD-EMFL, HZRD Dresden — [6]PSI, Villigen, Schweiz — [7]INMA, CSIC-U. Zaragoza, Spain — [8]ILL, Grenoble, France — [9]ct.qmat

Magnetic frustration, the competition among exchange interactions, often leads to novel magnetic ground states with unique physical properties which can hinge on details of interactions that are otherwise difficult to observe. Such states are particularly interesting when it is possible to tune the balance among the interactions to access multiple types of magnetic order. We present antlerite, $Cu_3SO_4(OH)_4$, as a potential platform for tuning frustration. Contrary to previous reports, the low-temperature magnetic state of its three-leg zigzag ladders is a quasi-one-dimensional analogue of the magnetic state recently proposed to exhibit spinon-magnon mixing in botallackite. Density-functional-theory calculations indicate that antlerite's magnetic ground state is exquisitely sensitive to fine details of the atomic positions, with each chain independently on the cusp of a phase transition, indicating an excellent potential for tunability.

MA 44.4 Thu 15:45 HSZ 403

High-Frequency Electron Spin Resonance Studies on the Quasi One-Dimensional Spin-1/2 Quantum Magnet $PbCuSeO_4(OH)_2$ — •Rahel Ohlendorf, Daniel Knauer, Changhyun Koo, and Rüdiger Klingeler — Kirchhoff Institute for Physics, Heidelberg, Germany

We report high-frequency ESR studies on a polycrystalline sample of the frustrated quasi-1D spin-1/2 quantum material $PbCuSeO_4(OH)_2$, isostructural to the well-studied natural mineral linarite ($PbCuSO_4(OH)_2$). Magnetisation data show the evolution of a magnetically ordered phase below $T_N = 4.8$ K and a spin-flop transition at $B_{SF} = 2.8$ T. A complex magnetic phase diagram is constructed from the data. ESR measurements on a loose powder evidence a gapless linear excitation mode within the ground state, which can be traced across the spin-flop transition, as well as two linear excitation modes within the in-field phase with a zero field gap of -31 ± 9 GHz and 32.9 ± 1.4 GHz, respectively. Measurements on fixed powder reveal a gapped magnon mode in the ground state with a zero field splitting of 70 ± 20 GHz. This mode might be accounted for by assuming an excitation of a spiral spin order in the ground state. Tracing the resonance positions with temperature suggests an easy-axis-type anisotropy with the paramagnetic g-factors 2.3 and 2.07. Changes in resonance position evidence the onset of short range fluctuations at around 70 K corresponding to $14 \times T_N$.

15 min. break

MA 44.5 Thu 16:15 HSZ 403

K_2ReCl_6: an unconventional Jahn-Teller system? — •Alexandre Bertin[1], Tusharkanti Dey[1], Daniel Brüning[1], Dmitry Gorkov[1,2], Kevin Jenni[1], Astin Krause[1], Petra Becker[3], Ladislav Bohatý[3], Daniel Khomskii[1], Thomas Lorenz[1], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München — [3]Abteilung Kristallographie, Institut für Geologie und Mineralogie, Universität zu Köln

Antifluorite compounds of chemical formula K_2MX_6 (where M is a transition metal and X=Cl,Br) can exhibit various crystallographic phase transitions, often understood by the softening of rotary phonon modes of the ligand octahedra surrounding the central transition metal. Among this family, K_2ReCl_6 exhibits on cooling four distinct structural phases and may constitute a playground to investigate the interplay between spin-orbit coupling (SOC) and Jahn-Teller (JT) effect. The question whether one of the crystallographic phase transitions is JT driven will be tackled by presenting a detailed temperature dependent structural study of K_2ReCl_6 and of its non magnetic counterpart K_2SnCl_6 by means of powder and single crystal XRD. With neutron diffraction experiments and by taking the low temperature monoclinic symmetry into account, the magnetic structure was solved. Frustration is only partially lifted by the structural distortions and the magnetic order causes further symmetry reduction. Finally, the strong magneto-elastic effect seen in thermal expansion measurements will be discussed in terms of domain re-orientation and weak ferromagnetism.

MA 44.6 Thu 16:30 HSZ 403

Non-collinear magnetism and Fe-R interaction in $R_3Fe_3Sb_7$ — •Felix Seewald[1], Falk Pabst[2,5], Sabrina Palazzese[1,3,5], Vadim Grinenkov[1,6], Hubertus Luetkens[7], Thomas Herrmannsdörfer[3], Shingo Yamamoto[3,5], Denis Gorbunov[3,5], Sumanta Chattopadhyay[3,5], Clemens Ritter[4], Kati Finzel[2], Thomas Doert[2,5], Michael Ruck[2,5], Jochen Wosnitza[1,3,5], and Hans-Henning Klauss[1] — [1]IFMP, TU Dresden, Germany — [2]Fakultät für Chemie und Lebensmittelchemie, TU Dresden, Germany — [3]HLD-EMFL, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]Institute Laue-Langevin Grenoble, France — [5]Würzburg-Dresden Cluster of Excellence ct.qmat — [6]Tsung-Dao Lee Institute, Shanghai, China — [7]PSI, Villingen, Switzerland

In $R_3Fe_3Sb_7$ (R = Pr, Nd) Fe and R atoms form columns of stacked triangles separated by Sb. Fe exhibits non-collinear ferromagnetic order below $T_c \approx 380$ K. On cooling at the onset of R order a spin reorientation ($T_{SRT,Pr} \approx 40$ K, $T_{SRT,Nd} \approx 50$ K) and magnetization reversal is observed [1].

Mössbauer spectra show two distinct magnetic Fe sites between T_c and T_{SRT}, both collapsing into one new site below T_{SRT}, reaching a static magnetic hyperfine-field of $B_{Hyp} = 20.59(21)$ T at 4.2 K. The data is the same for Nd and Pr except for the value of T_{SRT}. The local field obtained from μSR investigations is consistent with Mössbauer hyperfine-field at high temperatures. We will discuss the implications of our findings on the magnetic structure of the system.

[1] Falk Pabst, Sabrina Palazzese et. al., Advanced materials, accepted

MA 44.7 Thu 16:45 HSZ 403

Reentrant topological magnetic order and a spin-cholesteric phase in the $Sr_3Fe_2O_7$ perovskite — •Nikita Andriushin[1], Nikolai Pavlovskii[1], Yuliia Tymoshenko[1], Darren C. Peets[1], Alexandre Ivanov[2], Jacques Ollivier[2], Bernhard Keimer[3], Oksana Zaharko[4], and Dmytro Inosov[1] — [1]TU Dresden, Germany — [2]ILL, Grenoble, France — [3]MPI for Solid State Research, Stuttgart, Germany — [4]PSI, Villigen, Switzerland

Topologically nontrivial magnetic structures, e.g., skyrmion lattices and magnetic vortex crystals, are well known in noncentrosymmetric materials, so that antisymmetric exchange interactions are allowed. Only recently, topological multi-**q** magnetic textures that spontaneously break the chiral symmetry, for example three-dimensional hedgehog lattices, were discovered in centrosymmetric compounds, where they are instead driven by frustrated interactions. Here we show that the bilayer perovskite $Sr_3Fe_2O_7$, previously believed to adopt a simple single-**q** spin-spiral order, hosts two distinct types of multi-**q** topological spin textures. Its ground state represents an unusual multi-**q** spin texture with unequally intense helical spin modulations at the two ordering vectors. It is followed in temperature by a new "spin cholesteric" phase, in which the chiral symmetry is spontaneously broken along one of the crystal directions, but the weaker modulation along the orthogonal direction melts, giving rise to intense short-range dynamical fluctuations. Shortly before the transition to the paramagnetic state, a more conventional skyrmion-lattice order spanned by two equivalent **q** vectors emerges.

MA 44.8 Thu 17:00 HSZ 403

Incommensurate and multiple-q magnetic misfit order in $Cu_3SO_4(OH)_4$ — •Anton Kulbakov[1], Elaheh Sadrollahi[1], Florian Rasch[1], Maxim Avdeev[2,3], Sebastian Gass[4], Laura Bohorquez[4], Anja Wolter[4,5], Manuel Feig[6], Roman Gumeniuk[6], Hagen Poddig[7], Markus Stötzer[8], Jochen Litterst[9], Ines Puente-Orench[10,11], Andrew Wildes[11], Eugen Weschke[12], Jochen Geck[1,5], Dmytro Inosov[1,5], and Darren Peets[1] — [1]IFMP, TU Dresden, Germany — [2]ANSTO, Australia — [3]USYD, Australia — [4]IFW Dresden, Germany — [5]ct.qmat, TU Dresden, Germany — [6]TUBA Freiberg, Germany — [7]ACII, TU Dresden, Germany — [8]ACI, TU Dresden, Germany — [9]IPKM, TU Braunschweig, Germany — [10]INMA, Spain — [11]ILL, Grenoble, France — [12]HZB, Berlin, Germany

In antlerite, $Cu_3SO_4(OH)_4$, Cu^{2+} ($S = \frac{1}{2}$) quantum spins populate three-leg zigzag ladders in a highly frustrated quasi-one-dimensional structural motif. We demonstrate that at zero applied field, in addition to its recently reported low-temperature phase of coupled ferromagnetic and antiferromagnetic spin chains, this mineral hosts an incommensurate helical+cycloidal state, an idle-spin state, and a multiple-q phase which is the magnetic analog of misfit crystal structures. The antiferromagnetic order on the central leg is reentrant. The high tunability of the magnetism in antlerite makes it a particularly promising platform for pursuing exotic magnetic order.

MA 44.9 Thu 17:15 HSZ 403

Spin-liquid and Spin-glass states in Frustrated Tetragonal Pyrochlore $Zn_{0.8}Cu_{0.2}FeMnO_4$ — •Suchit Kumar Jena[1], Manfred Reehuis[2], and Subhash Thota[1] — [1]Department of Physics, Indian Institute of Technology Guwahati, Assam-781039, India — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, D-14109 Berlin, Germany

Spinel (AB_2O_4) Pyrochlore lattices are capable of generating high degree of magnetic frustration owing to tunable competing exchange interactions achieved via suitable magnetic elements on B site together with non-magnetic A site, which leads to quantum spin-liquid/Ice state [1]. One such compound is cubic $ZnFe_2O_4$, which manifests high magnetic frustration index ($f \simeq 12$) with antiferromagnetic Néel temperature, $T_N \sim 10$K [2]. Our results based on the neutron powder diffraction analysis shows that polycrystalline tetragonal $Zn_{0.8}Cu_{0.2}FeMnO_4$ (ZCFMO) lacks presence of long-range magnetic ordering. The dynamic ac magnetic susceptibility (χ' and χ'') measurements show multiple anomalies across 9K, 47K and 79K. Frequency dispersion in the loss spectrum ($\chi''(f,T)$) analyzed by employing empirical scaling-laws such as Vogel-Fulcher law and Power Law: $\tau = \tau_0[(T - T_{SG})/T_{SG}]^{-z\nu}$, yields cluster spin-glass state in ZCFMO with the spin freezing temperature (T_{SG}) at 41.8K and critical exponent $z\nu$=8.9, below the ferrimagnetic Néel temperature $T_{FiM} \simeq 79$K. These results are further supported by the heat capacity ($C_p(T)$) studies. Below 9K, $C_p \sim T^2$, indicates co-existence of spin-glass and spin-liquid states in ZCFMO.

[1] *Phys. Rev. B* **28**, 1 (1983). [2] *Phys. Rev. B* **66**, 064401 (2002).

MA 45: Members' Assembly

Time: Thursday 18:00–19:00 Location: HSZ 04

All members of the Magnetism Division are invited to participate.

MA 46: Ultrafast Magnetization Effects II

Time: Friday 9:30–12:45 Location: HSZ 02

MA 46.1 Fri 9:30 HSZ 02

Spin noise in magnetically ordered models — •Julius Schlegel, Martin Evers, and Ulrich Nowak — Department of Physics, University of Konstanz

Spin noise spectroscopy has emerged in the last years as a new tool to investigate magnetic material properties [1].

On the basis of a classical Heisenberg model and the stochastic Landau-Lifshitz-Gilbert equation of motion we numerically compute the time evolution of magnetically ordered structures on a time scale of several hundreds of picoseconds. By analyzing the spectral noise power density and the autocovariance of the magnetization in both ferro- and antiferromagnetic models, we find that the magnetic noise in thermal equilibrium comprises several features of the system. Resonances in the noise spectra are observed, which can be assigned to the eigenmodes of the magnetic structure. Moreover, the noise can mark phase transitions like the transition to the paramagnetic state or a spin-flop transition.

We thus conclude that by means of investigating the noise of the magnetization, the magnetic order of a system can be extracted even in cases where the mean equilibrium magnetization does not reflect the transition at all.

[1] Valerii S. Zapasskii, "Spin-noise spectroscopy: from proof of principle to applications", Adv. Opt. Photon. 5, 131-168 (2013)

MA 46.2 Fri 9:45 HSZ 02

Spin and momentum resolved ultrafast carrier dynamics in antiferromagnetic Dirac semimetal models — •Marius Weber[1], Kai Leckron[1], Baerbel Rethfeld[1], Libor Šmejkal[2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, Germany

Systems with antiferromagnetic ordering in real space often exhibit topological features in momentum space that only recently have been investigated in a comprehensive fashion [1]. For instance, depending on the magnetic ordering, they may have band structures with a pronounced anisotropy in band energies and in the spin structure of their single-particle states due to Dirac fermions. We present numerical calculations of the electron dynamics due to electron-phonon interactions [2,3] in model systems with two-dimensional k-space that capture key properties of antiferromagnetic Dirac materials in momentum space. After an instantaneous heating of the electronic system we obtain a transient carrier distributions, which reflect the momentum-space features. Surprisingly, completely anisotropic carrier distribution may evolve, even from excited carrier distributions that are isotropic in energy, i.e., f(E(k)) = f(E).

[1] L. Šmejkal et al.; Phys. Rev. Let 118, 106402 (2017).
[2] K. Leckron et al.; Phys. Rev. B 96, 140408 (2017).
[3] S. Essert et al., Phys. Rev. B 84, 224405 (2011).

MA 46.3 Fri 10:00 HSZ 02

Inertial spin dynamics in ferromagnets and antiferromagnets — Ritwik Mondal[1], Lucas Winter[2], Sebastian Grossenbach[2], Ulrich Nowak[2], and •Levente Rózsa[2,3] — [1]Indian Institute of Technology (ISM) Dhanbad, Dhanbad, India — [2]University of Konstanz, Konstanz, Germany — [3]Wigner Research Centre for Physics, Budapest, Hungary

Inertial spin dynamics emerges in magnetic materials at very short time scales where the directions of the atomic magnetic moment and angular momentum become separated, and nutation can be observed. The inertia gives rise to additional high-frequency or nutational excitations recently detected in ferromagnetic resonance experiments [1].

Here the signatures of inertial spin dynamics are discussed theoretically in ferromagnets (FMs) and antiferromagnets (AFMs). The nutational spin-wave bands are shifted by a constant frequency compared to the low-frequency bands in FMs, while in AFMs the nutational bands have a maximum in the center of the Brillouin zone [2]. It is demonstrated that a resonant excitation of the nutation may be utilised for switching the order parameter [3]. The switching is found to proceed faster in AFMs than in FMs, and in AFMs tuning the excitation frequency can be used to control the direction of the switching.

[1] K. Neeraj et al., Nat. Phys. 17, 245 (2021).
[2] R. Mondal et al., Phys. Rev. B 106, 134422 (2022).
[3] L. Winter et al., arXiv:2207.08566.

MA 46.4 Fri 10:15 HSZ 02

Magnetic field-dependent ultrafast control of an antiferromagnet — •Abeer Arora[1,6], Yoav Will Windsor[2], Sang-Eun Lee[1], Jit Sarkar[1], Kristin kliemt[3], Ch. Schüssler-Langeheine[4], Niko Pontius[4], Cornelius Krellner[3], Denis V. Vyalikh[5], and Laurenz Rettig[1] — [1]FHI der MPG, Berlin — [2]IOAP, TU Berlin — [3]Phy. Inst., Goethe-Uni., Frankfurt am Main — [4]HZB für Materialien und Energie GmbH, Berlin — [5]DIPC, Basque, Spain — [6]Fachbereich Physik, FU Berlin

Antiferromagnetic (AF) materials offer faster manipulation of spins, while making control of magnetic order challenging. A promising approach is utilizing the magnetic anisotropy (MA) to manipulate the spin arrangement on femtosecond timescales [1]. In addition, external magnetic fields can induce a spin flop (SF), providing an additional control knob for AF order. Understanding the interplay of these effects is of strong interest. Here, we present time-resolved resonant soft X-ray diffraction (RSXRD) experiments on the prototypical A-type antiferromagnet $GdRh_2Si_2$. We observe a coherent rotation of the AF arrangement followed by oscillations of the AF order due to light-induced change in the MA potential. Remarkably, upon increasing magnetic field, the frequency of the oscillations increases while the amplitude of reorientation upon photoexcitation decreases. These observations demonstrate the interplay of the MA potential and the SF field, and offer new ways towards deterministic control of AF spin order. [1]Windsor et al. Commun Phys 3, 139 (2020)

MA 46.5 Fri 10:30 HSZ 02

Dynamics of the Morin transition in hematite — •Maik Kerstingskötter[1], Tobias Dannegger[1], András Deák[2], László Szunyogh[2,3], and Ulrich Nowak[1] — [1]Department of Physics, University of Konstanz — [2]Department of Theoretical Physics, Budapest University of Technology and Economics — [3]ELKH-BME Condensed Matter Research Group, Budapest University of Technology and Economics

Below a critical temperature T_M of about 264 K, hematite is a perfect antiferromagnet with zero net magnetization due to the fact that the spins of the four sublattices are antiparallel and aligned with the *c*-axis. If the temperature exceeds this critical point, the spins reorient into the basal plane and assume a small canting angle that results in a finite net magnetization. This first-order phase transition from the antiferromagnet to the weak ferromagnetic phase is the Morin transition. While the equilibrium properties are well known, we want to investigate the nonequilibrium dynamics of the transition. Here we use atomistic spin dynamics simulations on the basis of an ab initio model to study the system's response to an instantaneous temperature increase from $T < T_M$ to $T > T_M$. In the model used, we indeed observe this Morin transition, which takes place in the range of five to a few hundred picoseconds, depending on the size of the Gilbert damping used.

MA 46.6 Fri 10:45 HSZ 02

Non-collinear spin reorientation in FeRh from first principles: Ultrafast laser quenching vs. coherent rotation of Fe moments — •Mike Jos Bruckhoff, Markus Ernst Gruner, and Rossitza Pentcheva — Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg - Essen

The binary alloy FeRh exhibits a metamagnetic first-order phase transition from antiferromagnetic (AFM) to ferromagnetic (FM) order, which can be driven by an external magnetic field or laser excitation. Here, we present a comprehensive non-collinear density functional theory study, where we investigate the multidimensional energy landscape $E(M,V)$, by constraining the total spin moment in order to compare different kinds of spin reorientation pathways. The absence of significant energy barriers suggests that the coherent in-plane rotation of the Fe moments is a likely scenario for the magnetic phase transition in an external magnetic field. In contrast to this, FeRh exhibits an laser-induced ultrafast demagnetization, which is initiated by optical inter-site spin transfer (OISTR) and a net Rh-to-Fe charge transfer at early times after excitation. We study extensively the response of FeRh to laser pulses with different laser parameters in both magnetic phases, simulated by means of real-time time-dependent DFT (RT-TDDFT). We find that the magnitude of the response strongly depends on the incident laser pulse, as well as the magnetic state of FeRh. We conclude that laser excitations and applied magnetic fields initiate distinct transition pathways, which may be exploited to control the phase transition by the external stimuli.

MA 46.7 Fri 11:00 HSZ 02

Signature of spatial gradients in ultrafast demagnetization observed with angle-resolved complex magneto-optical Kerr-effect (CMOKE) — •Sanjay Ashok[1], Jonas Hoefer[1], Martin Stiehl[1], Martin Aeschlimann[1], Hans Christian Schneider[1], Bärbel Rethfeld[1], and Benjamin Stadtmüller[1,2] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, Germany

Understanding the laser-induced ultrafast magnetization dynamics of thick metallic films is even in simple materials still challenging due to different transport mechanisms contributing to the magnetization dynamics. While heat- and particle diffusion are slow processes, ballistic and superdiffusive transport lead to an ultrafast equilibration of spatial inhomogeneities. However, quantifying experimentally their impact on ultrafast demagnetization of bulk material is difficult, since surface-sensitive experimental techniques integrate the response of the material over a certain depth.

Our theoretical calculations reveal that the Kerr-rotation dynamics is nearly insensitive to gradients in magnetization. In contrast, we find a strong influence for the angle-resolved ellipticity dynamics. These findings are confirmed by CMOKE experiments on Nickel films of varying thicknesses. The probe-angle resolved CMOKE technique thus provides a method to study the presence of transient gradients in magnetization at ultrafast timescales.

MA 46.8 Fri 11:15 HSZ 02

Dynamic versus Static Spectral Weight Transfer in LPCMO Thin Films — •Karen P. Stroh, Tim Titze, Pia Henning, Daniel Steil, Stefan Mathias, and Vasily Moshnyaga — I. Physikalisches Institut, Georg-August-Universität Göttingen, DE

$(La_{1-y}Pr_y)_{1-x}Ca_xMnO_3$ (LPCMO) is a prototypical bandwidth-controlled manganite with strong electron-phonon coupling and colossal magnetoresistance (CMR), originating from a nm-scale phase separation with ferromagnetic nanodomains antiferromagnetically coupled by correlated Jahn-Teller polarons (CPs).

The present study made use of strain-engineered LPCMO thin films prepared by a metalorganic aerosol deposition technique on LAO-buffered STO(100) substrates. Temperature-dependent static reflectivity spectra, showing the phase-transition-mediated spectral weight transfer (SWT), served as reference for identifying thermally driven behaviour. Further, pump-probe reflectivity (PPR) and time-resolved magneto-optical-Kerr effect (MOKE) data at different temperatures and probe wavelengths provided insights into the role of CPs in ultrafast electron and magnetization dynamics on femto- to nanosecond timescales.

As a main result, we observed a long-lived non-thermal state with increased optical conductivity in the polaron hopping regime at a probe energy of 0.7eV, indicating the destruction of polarons or a loss of their correlation upon laser excitation.

Financial support by the German Research Foundation DFG (project 399572199 and CRC 1073/A02) is acknowledged.

MA 46.9 Fri 11:30 HSZ 02

Experimental exploration of criticality in dynamic magnetic phase transitions — •Mikel Quintana and Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain.

The dynamic phase transition (DPT) of ferromagnets is a well-known phenomenon describing an abrupt change in the time-evolution behavior of magnetization in the presence of a time-dependent magnetic field. Its similarities with the conventional thermodynamic phase transition (TPT), particularly in terms of scaling behavior close to their respective critical points, are of utmost importance to understand collective behaviors in systems out-of-equilibrium [1]. However, a lack of experimental verification of these theoretical predictions has impeded further progress in the field up to now. Here, we experimentally explore for the first time the scaling behavior and critical exponents of the DPT in ultrathin Co films by means of real-time magneto-optical Kerr effect measurements in the relevant dynamic phase space. Surprisingly, we observe that the DPT and TPT critical exponents correspond to different dimensionalities for the same film. Our results seem to indicate different dimensional crossover length-scales for the TPT and DPT, a fact that has not been explored to date. [1] P. Riego et. al., Physica B 549, 13-23 (2018).

MA 46.10 Fri 11:45 HSZ 02

Slow dynamics from ultrafast phononic driving in $CuGeO_3$ — •Leonie Spitz[1], Eugenio Paris[1], Flavio Giorgianni[1], Bruce Normand[1], Thorsten Schmitt[1], and Christian Rüegg[1,2,3,4] — [1]Paul Scherrer Institute, CH-5232 Villigen-PSI, Switzerland — [2]Department of Quantum Matter Physics, University of Geneva, CH-1211 Geneva, Switzerland — [3]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland — [4]Institute of Quantum Electronics, ETH Zürich, CH-8093 Hönggerberg, Switzerland

The coherent manipulation of magnetism by optically driven phonons is a rapidly growing field [1-4]. However, experimental studies of quantum spin systems by ultrafast pump-probe schemes remain rare, because the most common optical techniques to probe magnetic phenomena fail in the absence of magnetic order. We present a multi-method study of the spin-chain material $CuGeO_3$, in which the magnetic correlations are associated with a lattice instability, also called the spin-Peierls (SP) transition, that drives the system into a collective singlet ground state of spin dimers [5]. By the coherent driving of phonons we observe low-frequency dynamics of the optical response which may offer new insight into the mechanism driving the SP transition in $CuGeO_3$, a problem that has remained unsolved for almost 3 decades.

[1] T. F. Nova et al., Nat. Phys. 13, 132-136 (2017). [2] A. S. Disa et al., Nat. Phys. 16, 937-941 (2020). [3] D. Afansiev et al., Nat. Mater. 20, 607-611 (2021). [4] F. Giorgianni et al., arXiv:2101.01189 (2021). [5] M. Hase et al., Phys. Rev. Lett. 70, 3651 (1993).

MA 46.11 Fri 12:00 HSZ 02

Spin-lattice coupling in a Van der Waals ferromagnet on ultrafast time scales — •Hyein Jung[1,2], Victoria C. A. Taylor[2], Yoav William Windsor[1,2], and Ralph Ernstorfer[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Fritz Haber Institute der MPG, Berlin, Germany

Two-dimensional (2D) van der Waals (vdW) magnetic materials hold great potential for spintronic applications. Cr2Ge2Te6 (CGT) is one such material which exhibits ferromagnetism even at the monolayer limit. With functionality in mind, investigation of dynamic processes on their fundamental time scales is of great importance, in particular energy flow and coupling between subsystems (carriers, spins, lattice). Furthermore, we have recently shown that understanding lattice dynamics in ferromagnets is essential for a complete understanding ultrafast spin dynamics. Here we use femtosecond electron diffraction (FED) to study lattice dynamics in CGT and other 2D magnets. We discuss the interaction between magnetic order and the lattice, and the influence of studying such effects at the monolayer limit.

MA 46.12 Fri 12:15 HSZ 02

Modelling spin-lattice coupling in computer simulation — •Michael Saur[1], Markus Weissenhofer[1], Hannah Lange[2], Akashdeep Kamra[3], Sergiy Mankovsky[2], Svitlana Polesya[2], Hubert Hubert[2], and Ulrich Nowak[1] — [1]University of Konstanz, Germany — [2]LMU Munich, Germany — [3]Universidad Autónoma de Madrid, Spain

We develop a multiscale framework for the description of spin-lattice coupling in computer simulations [1]. The derived Hamiltonian describes a closed system of spin and lattice degrees of freedom and explicitly conserves the total momentum, angular momentum and energy. Using a new numerical implementation that corrects earlier Suzuki-Trotter decompositions we perform simulations on the basis of the resulting equations of motion to investigate the combined magnetic and mechanical motion of a ferromagnetic nanoparticle. The framework developed herein will enable the use of multi-scale modeling for investigating and understanding a broad range of spin-phonon-mediated phenomena from slow to ultrafast time scales.

[1] M. Weißenhofer, H. Lange, A. Kamra, S. Mankovsky, S. Polesya, H. Ebert, U. Nowak, doi 10.48550/ARXIV.2211.02382

MA 46.13 Fri 12:30 HSZ 02

Ultrafast energy flow in the van der Waals ferromagnet Fe3GeTe2 (FGT) — •Yoav William Windsor[1,2], Daniela Zahn[2], Victoria C. A. Taylor[2], Theodor Griepe[4], Tommaso Pincelli[2], Hyein Jung[2], Sang-Eun Lee[2], Christian Schüssler-Langeheine[3], Niko Pontius[3], Unai Atxitia[4], Ralph Ernstorfer[1,2], and Laurenz Rettig[2] — [1]TU Berlin — [2]Fritz Haber Inst. — [3]Helmholz Zentrum Berlin — [4]CSIC Madrid

Van der Waals bonded magnetic materials expand the technological promise of 2D materials (TMDCs, Graphene) into the field of spintronics. To this end, understanding their nonequilibrium behavior is essential. Here we experimentally probed the response of FGT to photoexcitation using three probes: time-resolved ARPES (probes the carriers), time-resolved XMCD (probes the spins), and femtosecond electron diffraction (FED; probes the lattice). We resolve sub-picosecond responses in all three sub-systems, and find that the conventional M3TM model must be modified to reliably reproduce the combined response of all three sub-systems together.

MA 47: Skyrmions IV

Time: Friday 9:30–12:30 Location: HSZ 04

MA 47.1 Fri 9:30 HSZ 04

Systematic parameter study of magnetic skyrmions and antiskyrmions stabilised by exchange interactions — •Stephan von Malottki and Geoffroy Hautier — Thayer School of Engineering at Dartmouth College, Hanover, NH, USA

It is a major ongoing task to optimize the thermal stability of magnetic skyrmions (Sk) and antiskyrmions (ASk), which is in particular limited for sub-10 nm Sk and ASk in 2D magnetic materials. We focus on a stabilisation of Sk and ASk by exchange frustration [1] and higher order exchange interactions (HOI) [2]. We explore the large interaction parameter space of the atomistic Heisenberg model, consisting of exchange interaction beyond nearest neighbours, DMI, magnetocrystalline anisotropy and HOI by means of highly automatised energetic optimisation and geodesic nudged elastic band method (GNEB) simulations. Here we present the resulting sizes and energy barriers for SK and ASK in ferromagnetic and antiferromagnetic lattices with hexagonal and square geometry. This enables us to identify systematically the areas of parameters space in which metastable Sk and ASk can exist and how much their energy barriers can be enhanced in the framework of the atomistic extended Heisenberg model beyond nearest neighbours.

[1] S. von Malottki et al., Sci. Rep. 7, 12299 (2017)
[2] S. Paul et al., Nat. Commun. 11, 4756 (2020)

MA 47.2 Fri 9:45 HSZ 04

Coarse-graining skyrmion ensemble analysis — •Thomas Brian Winkler[1], Jan Rothörl[1], Maarten A. Brems[1], Hans Fangohr[2,3], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Germany — [2]Faculty of Engineering and Physical Sciences, University of Southampton, United Kingdom — [3]Max Planck Institute for the Structure and Dynamics of Matter Hamburg, Hamburg

Magnetic skyrmion are heavily investigated due to their interesting physics and their potential for unconventional computing schemes [1,2]. In confined geometries the thermal diffusion of skyrmions depends heavily on the ability of the skyrmion ensemble to arrange with respect to the confinement in a commensurate manner [3,4]. If external forces like spin-orbit torques are applied to such systems, the steady states of the system might change. We use a coarse-graining to analyse the system with methods from statistical physics [5] to ascertain the relevant states that the collective system is entering. We find in a simulational case study of four skyrmions in a triangular geometry that the steady states of a system are changing when external forces are applied. Such analysis is useful to optimise geometries or readout positions of magnetic tunnel junctions for skyrmion-based devices. [1] K. Everschor-Sitte et al., Journal of Applied Physics 124, 240901 (2018). [2] K. Raab et al., Nat. Comm. 13, 6982 (2022). [3] C. Song et al., Adv. Funct. Mater. 31, 2010739 (2021). [4] A. F. Schäffer et al., Commun Phys 2, 72 (2019). [5] B. Reuter et al., J Chem. Theory Comput. 14, 3579 (2018).

MA 47.3 Fri 10:00 HSZ 04

Dzyaloshinskii-Moriya interactions in skyrmionic lacunar spinel GaV_4S_8 — •Vladislav Borisov[1], Patrik Thunström[1], Anna Delin[2,3], and Olle Eriksson[1,4] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden — [3]SeRC (Swedish e-Science Research Center), KTH Royal Institute of Technology, Stockholm, Sweden — [4]Örebro University, Örebro, Sweden

Using the first-principles full-potential linear muffin-tin orbital method and magnetic force theorem we study the Heisenberg and Dzyaloshinskii-Moriya interactions in the lacunar spinel GaV_4S_8. This material hosts magnetic Néel skyrmions, in contrast to most other bulk magnets. The symmetry of the calculated DM vectors agrees with the C_{3v} structural symmetry and supports the stability of Néel skyrmions. The sizes of the magnetic interactions show some variations as a function of electronic correlations. These changes are also reflected in the estimated wavelength of the helical magnetic state. Our theoretical results indicate that the electronic and magnetic properties depend strongly on the spin configuration of the V_4 clusters, on which there is no clear consensus in the literature, and we make a suggestion for the configuration that fits better to the known measurements.

MA 47.4 Fri 10:15 HSZ 04

On the correlation between spin, orbital and chiral magnetizations of skyrmions — Imara Lima Fernandes[1] 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 & CENIDE, 47053 Duisburg, Germany

Skyrmions are spin-swirling textures hosting wonderful properties with potential implications in information technology. The magnetization carried by such objects is prospected as a mean of encoding magnetic bits while their topological nature gives rise to a plethora of exquisite features such as topological protection, the skyrmion Hall effect, topological Hall effect and topological orbital moment [1]. Here, the emergent magnetic field, which is directly proportional to the three-spin scalar chirality χ, plays a key role. We explore from ab-initio the rich set of magnetizations carried by single small magnetic skyrmions generated in PdFe bilayer on Ir(111) surface and focus on the correlation between spin, orbital, chiral magnetizations and χ after being excited by single atomic defects [2]. We identify a universal pattern that can guide the design of storage devices by engineering the magnitude of the magnetization carried by skyrmions via controlled implantation of defects.

–Work funded by the Priority Programmes SPP 2137 "Skyrmionics" and SPP 2244 "2D Materials" of the DFG (Projects LO 1659/8-1 and LO 1659/7-1). [1] dos Santos Dias et al. Nat. Commun. 7, 13613 (2016); [2] Lima Fernandes et al. Nat. Commun. 9, 4395 (2018).

MA 47.5 Fri 10:30 HSZ 04

Nature of magnetic Exchange interactions in Centrosymmetric Hexagonal NiMnGa — •Sunil Wilfred DSouza[1], Sanjay Singh[2], and Jan Minár[1] — [1]New Technologies Research Centre, University of West Bohemia, Univerzitní 8, CZ-306 14 Pilsen, Czech Republic. — [2]School of Materials Science and Technology, Indian Institute of Technology (Banaras Hindu University) Varanasi-221005, India.

Hexagonal NiMnGa hosts Novel magnetic biskyrmion state in which vortex-like nanometric spin textures are stable over a wide temperature range extending upto the Curie temperature making it a contender for potential applications in future high-performance spintronic devices. We present, The Heisenberg exchange couplings determined from the paramagnetic phase using the disordered local moment theory which is found to give a significantly more realistic description in comparison with the treatment of the material as a ferromagnet. Frustration caused by competing ferromagnetic and antiferromagnetic exchange couplings at the nearest-neighbor Mn-Mn interactions has been noticed in NiMnGa which is known to lead to non-collinear magnetic ordering. Total energy calculations establishes a non-collinear spin-structure which is stable at a specific Mn spin canting angle in c-plane which is resulting from the magnetocrystalline anisotropy. The Mean-Field Curie temperature determined from the exchange interactions is in good agreement with experiment.

MA 47.6 Fri 10:45 HSZ 04

Skyrmions in 4*d*- and 5*d*-doped B20 compounds — •Vladislav Borisov[1], Qichen Xu[2,3], Nikolaos Ntallis[1], Rebecca Clulow[4], Vitalii Shtender[4], Johan Cedervall[5], Martin Sahlberg[4], Kjartan Thor Wikfeldt[6], Danny Thonig[7,1], Manuel Pereiro[1], Anders Bergman[1], Anna Delin[2,3], and Olle Eriksson[1,7] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden — [3]SeRC (Swedish e-Science Research Center), KTH Royal Institute of Technology, Stockholm, Sweden — [4]Department of Chemistry, Uppsala University, Sweden — [5]Department of Materials and Environmental Chemistry, Stockholm University, Sweden — [6]PDC Center for High Performance Computing, KTH Royal Institute of Technology, Stockholm, Sweden — [7]Örebro University, Örebro, Sweden

Based on theoretical calculations, we predict that 4*d*- and 5*d*-doped FeSi and CoSi compounds host skyrmions with a size between 50 nm for (Co,Os)Si and 148 nm for (Fe,Co)Si. Calculations are done using the full-potential linear muffin-tin orbital method and magnetic force theorem which allow to address the Heisenberg and Dzyaloshinskii-Moriya (DM) interactions, and the skyrmionic properties were determined using micromagnetic simulations. We find that the 5*d* doping (by Ir or Os) is particularly efficient in terms of enhancing the DM interaction. Convex-hull analysis suggests that the doped compounds are structurally stable, and we have managed to synthesize and characterize $Co_{1-x}Ru_xSi$ systems both in powder and single-crystal forms.

15 min. break

MA 47.7 Fri 11:15 HSZ 04

Bloch points in the ground state of chiral magnet nanocylinder — •Andrii Savchenko[1], Fengshan Zheng[2,3], Nikolai Kiselev[1], Luyan Yang[1,2], Qianqian Lan[1,2], Filipp Rybakov[4], Stefan Blügel[1], and Rafal Dunin-Borkowski[1,2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany — [3]Spin-X Institute, South China University of Technology, Guangzhou 511442, China — [4]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden

Experimental observation of Bloch points (BPs) is challenging since these topological defects represent energetically unfavorable configurations and usually appear only as a metastable state. The present study aims to find the systems where due to the competition between short-range and long-range interactions the BPs can emerge in the ground state of the system. A nanocylinder of an isotropic chiral magnet might be a good candidate for such a system. We found that the dipole string - the configuration containing two coupled BPs of opposite topological charge, at some geometrical parameters corresponds to the lowest energy state in such nanocylinder. Our micromagnetic simulations with realistic parameters agree well with the results of the transmission electron microscopy experiment on the FeGe sample.

MA 47.8 Fri 11:30 HSZ 04

Quantum correlation functions of magnetic skyrmions in chiral magnets — •Sopheak Sorn[1] and Markus Garst[1,2] — [1]Institute of Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

Recent research activities have turned to studying quantum effects in skyrmion-hosting ordered phases within the context of numerical diagonalization of quantum spin Hamiltonians as well as semiclassical magnonic theories. In the later, one can expand various operators in magnon fields around a classical spin-texture background. In this talk, I will present results from such a semiclassical theory for chiral magnets, focusing on various correlation functions involving the topological charge and the energy-momentum tensor at zero and nonzero temperature. I will also discuss how these correlation functions are related to linear responses of skyrmions to external perturbation.

MA 47.9 Fri 11:45 HSZ 04

Modeling stray fields using Bi-axial anisotropy in in-inplane magnets — •Venkata Krishna Bharadwaj[1], Karin Everschor-Sitte[2], Jairo Sinova[1,3], and Ricardo Zarzuela[1] — [1]Johannes Gutenberg-University, Mainz — [2]Faculty of Physics, University of Duisburg-Essen, D-47057 Duisburg, Germany — [3]Institute of Physics Academy of Sciences of the Czech Republic, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

Recently [1,2], magnetic bimreons, skyrmion analogs in in-plane magnetized films have gained interest due to their stark difference in current-driven dynamics with respect to Neel skyrmions showing unidirectional motion with SOT-driven torques. The other technological advantage is that they can be densely stacked without worrying about stray fields between the layers. However, the stray fields need to be handled carefully as they are not trivial as in out-of-plane films. In this work, we study the bi-axial anisotropy to model the stray field in in-plane magnetized films. We provide the phase diagram and look at the deformations of spin spiral phases and the presence of titled fields. Finally, we study the shape deformation of skyrmions due to stary fields and the effects in current-driven dynamics. [1] R. Zarzuela et al., Physical Review B 101, 054405 (2020), [2] B. Göbel, et al., Phys. Rev. B 99, 060407(R) (2019).

MA 47.10 Fri 12:00 HSZ 04

Magnetoelectric Cavity Magnonics in Skyrmion Crystals — Tomoki Hirosawa[1,2], •Alexander Mook[1,3,4], Jelena Klinovaja[1], and Daniel Loss[1] — [1]University of Basel, Basel, Switzerland — [2]Aoyama Gakuin University, Sagamihara, Kanagawa, Japan — [3]Technical University of Munich, Garching, Germany — [4]Johannes Gutenberg University, Mainz, Germany

We present a theory of magnetoelectric magnon-photon coupling in cavities hosting noncentrosymmetric magnets. Analogously to nonreciprocal phenomena in multiferroics, the magnetoelectric coupling is time-reversal and inversion asymmetric. This asymmetry establishes a means for exceptional tunability of magnon-photon coupling, which can be switched on and off by reversing the magnetization direction. Taking the multiferroic skyrmion host Cu_2OSeO_3 with ultralow magnetic damping as an example, we reveal the electrical activity of skyrmion eigenmodes and propose it for magnon-photon splitting of "magnetically dark" elliptic modes. Furthermore, we predict a cavity-induced magnon-magnon coupling between magnetoelectrically active skyrmion excitations. We discuss applications in quantum information processing by proposing protocols for all-electrical magnon-mediated photon quantum gates, and a photon-mediated split operation of magnons. Our study highlights magnetoelectric cavity magnonics as a novel platform for realizing coherent transduction between photons and magnons.

Reference: Tomoki Hirosawa*, Alexander Mook*, Jelena Klinovaja, and Daniel Loss, PRX Quantum 3, 040321 (2022)

MA 47.11 Fri 12:15 HSZ 04

Artificial surface conductivity on metallic metamaterials and its effect on localized plasmon skyrmions — •Amin Khavasi[1] and Karin Everschor-Sitte[1,2] — [1]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Center for Nanointegration Duisburg-Essen (CENIDE), Duisburg, Germany

Metallic metamaterials have been widely investigated for realizing different peculiar effects such as spoof surface plasmons [1] and extraordinary transmission of light [2]. Recently, topologically robust localized plasmonic skyrmions have been realized by spiral metallic metastructures [3, 4].

For metal films with a periodic arrangement of cut-through slits, Khavasi and others have shown that the structure can be modeled by an anisotropic medium with an artificial surface conductivity [5]. In the subwavelength regime, the surface conductivity is imaginary considering lossless systems representing non-specular higher diffracted orders.

We investigate the consequences of such artificial surface conductivities for the skyrmionic modes of the spiral meta-structures to obtain more insight on the behavior of the localized plasmonic skyrmions.

References:
[1] Pendry, J. B., et al., science 305, (2004): 847-848.
[2] Porto, J. A., et al., Physical review letters 83,(1999): 2845.
[3] Davis, T. J., et al. Science 368, (2020): eaba6415.
[4] Deng, Z., et al., Nature Communications 13, (2022): 1-7.
[5] Edalatipour, M., et al., Journal of lightwave technology 30, (2012): 1789-1794.

MA 48: Magnetic Instrumentation and Characterization

Time: Friday 9:30–11:45 Location: HSZ 401

MA 48.1 Fri 9:30 HSZ 401

Portable devices for adding Spatial-Intensity-Modulation-mode capabilities to polarized neutron beams — •Denis Mettus[1], Jonathan Leiner[1], Johanna Jochum[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

The MIEZE (Modulated IntEnsity with Zero Effort) resonant spin-echo technique at the RESEDA instrument at FRM II has its optimum resolution at small scattering angles, i.e. SANS type geometries. It is possible to extend the MIEZE application to wide angles by incorporating magnetic Wollaston prisms (MWPs) into the beamline. MWPs can produce controlled spatially intensity modulations in addition to the intensity modulations in time inherent to MIEZE. This would allow correcting to the neutron time of flight differences, extending the MIEZE resolution function to any desired scattering angle.

Additionally, MWPs will be useful in the context of intra-particle mode-entangled neutron beams for potential use in probing many-body quantum entanglement in materials. Finally, the compact and modular nature of the MWPs will allow them to be used to measure diffraction peaks with enhanced resolution at several polarized beam instruments such as KOMPASS, LaDiff, and in general at small angle neutron scattering instruments. We present the plans for the construction of these superconducting MWPs for use at FRM II, and describe the details of their operation and the various possibilities they offer.

MA 48.2 Fri 9:45 HSZ 401

A signal-integrating approach to second harmonic generation imaging and spectroscopy — Lea Forster[1], •Jan Gerrit Horstmann[1], Jannis Lehmann[1,2], Thomas Lottermoser[1], and Manfred Fiebig[1] — [1]Dept. of Materials, ETH Zurich, Switzerland — [2]RIKEN Center for Emergent Matter Science (CEMS), Japan

We investigate the impact of different data normalization procedures on the signal-to-noise ratio in second harmonic generation (SHG) imaging and spectroscopy. Using both nanosecond and femtosecond laser systems in combination with standard detection schemes for SHG, we find that uncorrelated noise in the detection electronics often dominates over the contributions of pulse-to-pulse fluctuations of the laser system, long-term power drifts, or time-dependent changes of the beam profile. Consequently, normalization of SHG signals averaged over thousands of pulses can yield similar signal-to-noise ratios comparable with pulse-to-pulse-normalized data. Based on these results, we demonstrate that state-of-the-art CCD or sCMOS cameras can, in many cases, replace photomultiplier tubes as detectors in pump-probe SHG measurements, enabling ultrafast high-resolution SHG imaging of nonequilibrium dynamics in solids.

MA 48.3 Fri 10:00 HSZ 401

New versatile instruments for magnetism research at ID12 of the ESRF — •A. Aubert[1], K. Skokov[1], G. Gomez[2,3], F. Wilhelm[3], A. Rogalev[3], H. Wende[2], O. Gutfleisch[1], and K. Ollefs[2] — [1]Functional Materials, TU Darmstadt (Germany) — [2]Fac. of Phys., Uni. Duisburg-Essen (Germany) — [3]ESRF, Grenoble (France)

I will introduce two new instruments which have been implemented at the beamline ID12 of the European Synchrotron Radiation Facility (ESRF), in the framework of the ULMAG project funded by BMBF (grant 05K2019). These instruments offer the ESRF users a unique possibility to measure under strictly the same experimental conditions the element-specific X-ray absorption spectroscopy (XAS)/X-ray magnetic circular dichroism (XMCD), XRD simultaneously with the measurement of various macroscopic properties (magnetization, magnetostriction, magnetocaloric, magnetoresistance), as a function of magnetic field (up to 17 T) and temperature (5-325 K) [1].

To demonstrate the potential and features of these scientific instruments, I will present two case studies: (1) FeRh, which has a first-order anti-ferromagnetic to ferromagnetic transition around room temperature (2) HoCo2, which exhibits a first-order ferrimagnetic to paramagnetic transition. These two cases demonstrate new horizons for studying the physics of magnetic materials, where the interplay between the magnetic, structural, and electronic subsystems of the solid is essential.

[1] A. Aubert et al. IEEE Instr. Meas. (2022) 10.1109/TIM.2022.3157001

MA 48.4 Fri 10:15 HSZ 401

XMCD in fluorescence-yield mode can measure the spin-orbit torque switching of both rare-earth and transition-metal sublattices in mesoscale devices of $GdFe_3$ thin films — •James M Taylor[1,2], Chen Luo[1,2], Victor Ukleev[1], Christian H Back[2], and Florin Radu[1] — [1]Helmholtz-Zentrum Berlin for Materials and Energy, 12489 Berlin, Germany — [2]Department of Physics, Technical University of Munich, 85748 Garching, Germany

Ferrimagnets containing one rare-earth and one transition-metal sublattice are of interest both for future spintronic devices and as sandbox materials for exploring ultrafast magnetism. In regard to the latter, ferrimagnetic Gd+Fe has been widely studied, due to its demonstration of all-optical switching (AOS). On the other hand, more interesting for technological applications is current-induced magnetization reversal driven by spin-orbit torques (SOTs). To fully understand SOT switching in ferrimagnets, it is important, as with AOS, to look at the respective behaviour of both sublattices. In this work, we take a step towards making such measurements more readily available: by using conventional, static x-ray magnetic circular dichroism (XMCD) operated in fluorescence-yield mode to measure the relative responses of the Gd and Fe sublattices during an SOT switching process. This was performed using sub-ms current pulses in μm-sized devices fabricated from $GdFe_3$ heterostructures down to 10 nm thick, in-situ in the VEKMAG beamline at the BESSY II synchrotron. We compare this with electrical detection of the switching using simultaneous anomalous Hall effect measurements, which follow the Fe sublattice, as expected.

15 min. break

MA 48.5 Fri 10:45 HSZ 401

Periodogram-based detection of unknown frequencies in time-resolved scanning transmission X-ray microscopy — •Simone Finizio[1], Joe Bailey[1,2], Bart Olsthoorn[3], and Jörg Raabe[1] — [1]Paul Scherrer Institut, Villigen PSI, Switzerland — [2]EPFL, Lausanne, Switzerland — [3]Nordita, KTH Royal Institute of Technology and Stockholm University, Stockholm, Sweden

Pump-probe time-resolved imaging is a powerful technique that enables the investigation of dynamical processes. Signal-to-noise and sampling rate restrictions normally require that cycles of an excitation are repeated many times with the final signal reconstructed using a reference. However, this approach imposes restrictions on the types of dynamical processes that can be measured, namely that they are phase locked to a known external signal (e.g. a driven oscillation or impulse). This rules out many interesting processes such as auto-oscillations and spontaneously forming populations e.g. condensates. In this work we present a method for time-resolved imaging, based on the Schuster periodogram, that allows for the reconstruction of dynamical processes where the intrinsic frequency is not known. In our case we use time of arrival detection of x-ray photons to reconstruct magnetic dynamics without using *a-priori* information on the dynamical frequency. This proof of principle demonstration will allow for the extension of pump-probe time-resolved imaging to the important class of processes where the dynamics are not locked to a known external signal and in its presented formulation can be readily adopted for x-ray imaging and also adapted for wider use.

MA 48.6 Fri 11:00 HSZ 401

Towards switchable probes for advanced Magnetic Force Microscopy — •Aniruddha Sathyadharma Prasad, Rachappa Ravishankar, Rudolf Schäfer, Volker Neu, Bernd Büchner, and Thomas Mühl — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

In magnetic force microscopy (MFM) on samples consisting of non-homogeneous materials and challenging topography, the "magnetic" contrast is often overwhelmed by additional non-magnetic forces arising from differing contact potentials and from changes in the capacitive coupling due to topographical features. The elimination of such interfering signals can be done by a differential imaging process with inverted tip magnetization. Earlier implementations either require precise repositioning of the probe after external switching of the magnetization or application of global magnetic fields which can cause changes in the sample. In our work, we overcome these difficulties by switching the magnetization externally, and using feature matching in the post processing step to eliminate the need for precise repositioning. We also showcase first steps towards an in-situ switching of MFM probes for developing a high-speed differential process within the MFM instrument. This involves the design and fabrication of planar micro-coils capable of providing sufficient magnetic field to switch high quality Iron filled Carbon Nanotube (FeCNT) MFM probes. The switching was verified by applying the inhomogeneous field distributions of planar micro-coils in micromagnetic simulation studies on a FeCNT. Preliminary MFM results from an FeCNT probe interacting with such a coil are also presented.

MA 48.7 Fri 11:15 HSZ 401

Measuring Antiferromagnets at Room Temperature in a Magnetically Shielded Environment — •Michael Paulsen[1], Silvia Knappe-Grüneberg[1], Jens Voigt[1], Allard Schnabel[1], Rainer Körber[1], Michael Fechner[2], and Dennis Meier[3] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg, Germany — [3]NTNU Norwegian University of Science and Technology, Trondheim, Norway

Antiferromagnetic materials possess zero net dipole magnetization. However, higher-order magnetizations, such as quadrupolar magnetic field contributions, have been predicted for non-centrosymmetric antiferromagnets. Classical low-temperature measurements on Cr_2O_3 [1] indeed indicated an external quadrupole field at 4.2 K [2, 3], but the validity of the results was put into question due to the limited sensitivity of the applied experiment. Here, we present magnetization measurements gained at room temperature in an ultra-low magnetic field environment (< 1 nT). A multi-channel setup with Superconducting Quantum Interference Devices (SQUIDs) and Optically Pumped Magnetometers (OPMs) are used as magnetic field detectors. The results corroborate the emergence of a quadrupolar far-field in Cr2O3, providing new opportunities for the characterization of antiferromagnets and materials with ultra-small remanent magnetization in general.

[1] I. Dzyaloshinskii, Sol. Stat. Comm. 82:7, 579-580, 1992.
[2] D. N. Astrov and N. B. Ermakov, JETP, 59:4, 274-277, 1994.
[3] D. N. Astrov et al, JETP Letters, 63:9, 745-751, 1996.

MA 48.8 Fri 11:30 HSZ 401

Improving the magnetic adhesion of a metal-pipe crawling robot using elastomeric toes — •Muhammad Khan, Kilian Schäfer, and Oliver Gutfleisch — Functional Materials, Institute of Materials Science, Technical University Darmstadt, D-64287 Darmstadt, Germany

To assist human inspectors who examine thousands of kilometres spread oil and gas pipelines, robots are being utilized. A key challenge in robotic pipeline inspection is to ensure that a robot does not fall off a metal pipe. In this work, we show that a two-legged robot crawls on metal pipes using its electromagnetic feet. The robot slip was fixed by introducing an elastomeric toe, implanted under the robot feet. It was shown that the soft toe increased the magnetic adhesion of the feet by enabling the stable stance of the robot feet. The behaviour of the foot-toe was further characterized by conducting surface adaptability test (measurement of toe deformation), calculating its coefficient of friction on different metal pipes, and real-world robot pipe-crawling experiments. Furthermore, use of a magneto-active compound consisting of hard magnetic Nd2Fe14B particles in a thermoplastic polyurethane (TPU) matrix, fabricated to form the fin-ray structure will be also discussed as a potential replacement of the electromagnet. However, such a fin-ray structure would require a large and continuously available activation field which is obviously highly challenging. Here, a concept demonstration at the miniature level can be shown by modifying the robot's shape and size, matching the miniature setup.

MA 49: Magnetic Information Technology, Recording, Sensing

Time: Friday 9:30–11:45 Location: HSZ 403

MA 49.1 Fri 9:30 HSZ 403

Spin revolution breaks time reversal symmetry of rolling magnets — •Elena Vedmedenko and Roland Wiesendanger — University of Hamburg

The classical laws of physics are usually invariant under time reversal. Here, we reveal a novel class of magnetomechanical effects rigorously breaking time-reversal symmetry. These effects are based on the mechanical rotation of a hard magnet around its magnetization axis in the presence of friction and an external magnetic field, which we call spin revolution. The spin revolution leads to a variety of symmetry breaking phenomena including upward propulsion on vertical surfaces defying gravity as well as magnetic gyroscopic motion that is perpendicular to the applied force. The angular momentum of spin revolution differs from those of the magnetic field, the magnetic torque, the rolling axis, and the net torque about the rolling axis. The spin revolution emerges spontaneously, without external rotations, and offers various applications in areas such as magnetism, robotics and energy harvesting.

E. Y. Vedmedenko and R. Wiesendanger, Spin revolution breaks time reversal symmetry of rolling magnets, Sci. Rep. 12, 13608 (2022).

MA 49.2 Fri 9:45 HSZ 403

Improved Planar Hall Effect sensors for fluid measurement techniques — •Jan Schmidtpeter, Thomas Wondrak, Denys Makarov, and Yevhen Zabila — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden Germany

Inductive flow measurement techniques such as the Contactless Inductive Flow Tomography require sensors that provide a magnetic field resolution of 1 nT while operating in magnetic fields of several mT. With advancements in state-of-the-art magnetoresistive thin-film sensors the required behavior regarding sensitivity, precision and hysteresis can be achieved [1]. Planar Hall Effect sensor have been shown to be one of the leading sensor types in this area. Therefore we present a detailed study on the effect of different sensor layouts, geometries, magnetic flux concentrators and other parameters on the characteristics of single layer Permalloy Planar Hall Effect sensors.

[1] Granell, Pablo Nicolás, et al. npj Flexible Electronics 3.1 (2019): 1-6.

MA 49.3 Fri 10:00 HSZ 403

Towards nanomechanical detection of fT magnetic fields — Dhavalkumar Mungpara, Torben Hänke, and •Alexander Schwarz — Institute of Nanostructure and Solid State Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg

This work has been conducted in the framework of the OXiNEMS project that aims to establish etching protocols for oxides similar to those nowadays available for silicon and to develop a novel all-oxide nano-mechanical sensor to detect bio-magnetic field in the fT-regime required for magnetoencephalography (MEG).

Our envisaged hybrid sensor consists of a superconducting loop with a constriction that functions as field-to-gradient converter and a magnetically sensitive mechanical resonator that detects the Oersted field above the constriction. To increase the signal above the thermal noise limit we present an optimized constriction-resonator arrangement that encompasses a spiral geometry instead of a single constriction. This optimized geometry, can be fabricated using up-to date technology and should be able reach a sensitivity of 10 fT/$\sqrt{Hz}$ at 77 K.

The OXiNEMS project (www.oxinems.eu) has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 828784. The author gratefully acknowledges the fruitful discussions with all members of the consortium, particularly Luca Pellegrino, Stefania Della Penna, Alexei Kalaboukhov, Federico Maspero, Nicola Manca, Simone Cuccurullo, Warner Venstra, Daniele Marré and Riccardo Bertacco.

MA 49.4 Fri 10:15 HSZ 403

Magnetic noise theory of magnetoelastic magnetic field sensors — •Elizaveta Spetzler[1], Benjamin Spetzler[2], and Jeffrey McCord[1] — [1]Institute for Materials Science, Kiel University, Kiel, Germany — [2]Department of electrical engineering and information technology, Technical University Ilmenau, Ilmenau, Germany

Intrinsic magnetic noise currently limits the performance of many magnetoelastic magnetic field sensors. Therefore, understanding and estimating the magnetic noise level is crucial for further sensor improvement. This work reviews the theory of thermal-magnetic noise in general and discusses additional magnetic noise sources relevant to magnetoelastic magnetic field sensors. We highlight the limitations and assumptions of previous approaches and develop important model extensions. We demonstrate and quantify the strong connection between magnetic sensitivity, loss, and noise by implementing the magnetic noise description in a multilevel model of a magnetoelastic magnetic field sensor based on the ΔE effect. The excellent match of simulations and measurements reveals a significant influence of the fundamental nonlinearity of the ΔE effect on the sensor performance. While the model is applied to ΔE effect sensors, many of the results are also valid for other magnetic field sensors and magnetoelastic modulated devices.

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.

15 min. break

MA 49.5 Fri 10:45 HSZ 403

Transfer printing of GMR sensing elements for curved electronics — •Bezsmertna Olha[1], Rui Xu[1], Eduardo Sergio Oliveros-Mata[1], Clemens Voigt[2], Sindy Mosch[2], Jürgen Fassbender[1], Mykola Vinnichenko[2], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]Fraunhofer Institute for Ceramic Technologies and Systems IKTS, 01277 Dresden, Germany

In the post-covid era, touchless interaction between human beings and environments is attracting more and more attentions. Sensors based on giant magnetoresistance (GMR) effect are widely considered as a workhorse to address this demand. However, the fabrication of GMR multi-layer elements face many limitations (e.g., inappropriate to substrates with curved and/or rough surfaces) due to the layer thickness dependence of performance. Here, we propose a transfer technique to overcome the aforementioned limitations. With the assistance of two sacrificial layers, a large scale and wrinkle-free coverage is realized on various substrates (of different materials, roughness, and curvatures) with little loss of GMR performance. Notably, such technique is easy processing, without the need of any substrate deformation, temporary carriers or high-temperature processing. The transferred sensors are integrated into skin-mountable electronics, successfully functioning as a human-machine interface.

MA 49.6 Fri 11:00 HSZ 403

Printed Giant Magnetoresistive Sensors — •Yevhen Zabila, Eduardo Sergio Oliveros Mata, Minjeong Ha, Gilbert Santiago Cañón Bermúdez, Rico Illing, Ingolf Mönch, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Printing is an affordable and high-throughput method to process electronics in soft substrates. Printable magnetoresistive pastes have been developed as an alternative single-step fabrication method to obtain magnetic field sensors. Until now, there were no examples of magnetic printed sensors that deliver steady sensing behavior upon mechanical stretching. Here, we will present low-noise printable magnetic field sensors sensitive down to sub-mT, which are mechanically stretchable after printing. The pastes are composites of poly(styrene-butadiene-styrene) copolymer (SBS) with embedded magnetoresistive microflakes. Our printed sensors were demonstrated to be used as electronic skin interfaces.[1]

[1] M. Ha, Y. Zabila, et. al. Adv. Mater. 33 (12), 2005521 (2021)

MA 49.7 Fri 11:15 HSZ 403

Printed magnetic field sensors based on bismuth showing large non-saturating magnetoresistance — •Eduardo Sergio Oliveros-Mata[1], Clemens Voigt[2], Gilbert Santiago Cañón Bermúdez[1], Zevhen Zabila[1], Rico Illing[1], Marco Fritsch[2], Sindy Mosch[2], Mihails Kusnezoff[2], Jürgen Fassbender[1], Mykola Vinnichenko[2], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Fraunhofer-Institut für Keramische Technologien und Systeme, Dresden, Germany

The development of functional inks allows to create novel printed electronics with unconventional form factors. Here, we show the fabrication of printed magnetic field sensors based on bismuth microparticles. Sensors showed non-saturating large magnetoresistance (146%, 5T, at room temperature), and resilience to mechanical bending (2000 cycles). We demonstrated large area magnetically sensitive interfaces such as smart locks and interactive wallpapers.[1]

[1] E.S. Oliveros-Mata, C. Voigt, et al. Adv. Mater. Technol. 2200227 (2022)

MA 49.8 Fri 11:30 HSZ 403

Self-healable printed magnetic field sensors using alternating magnetic fields — •Rui Xu[1], Gilbert Santiago Cañón Bermúdez[1], Oleksandr V. Pylypovskyi[1], Oleksii M. Volkov[1], Eduardo Sergio Oliveros Mata[1], Yevhen Zabila[1], Rico Illing[1], Pavlo Makushko[1], Pavel Milkin[2], Leonid Ionov[2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Bayreuth, Ludwig Thoma Str 36a, 95447 Bayreuth, Germany

Percolation network of fillers plays a critical role in rendering printable electronics functionality and durability1. We employ alternating magnetic fields (AMF) to drive magnetic fillers actively and guide the formation and self-healing of percolation networks2. Relying on AMF, we fabricate printable magnetoresistive sensors revealing an enhancement in sensitivity and figure of merit of more than one and two orders of magnitude relative to previous reports. These sensors display low noise, high resolution, and are readily processable using various printing techniques that can be applied to different substrates. The AMF-mediated self-healing has six characteristics: 100% performance recovery; repeatable healing over multiple cycles; room-temperature operation; healing in seconds; no need for manual reassembly; humidity insensitivity. By virtue of these advantages, the AMF-mediated sensors are used in safety application, medical therapy, and human-machine interfaces for augmented reality. 1 Nat. Electron. 2, 144-150 (2019); 2 Nat. Commun. 13, 6587 (2022).

MA 50: Magnetic Domain Walls (non-skyrmionic)

Time: Friday 9:30–11:15 Location: POT 6

MA 50.1 Fri 9:30 POT 6

Geometrically controlled domain wall dynamics in curved 3D nanostructures — •Sandra Ruiz-Gomez[1], Pamela Morales[1], Claudia Fernandez-Gonzalez[1], Aurelio Rodriguez-Hierro[2], Michael Foerster[3], Miguel Angel Nino[3], Ewa Madej[4], Dorota Wilgocka-Slezak[4], Anna Mandziak[4], Amalio Fernandez-Pacheco[5], and Claire Donnelly[1] — [1]MPI-CPfS, Dresden, Germany — [2]Nothnitzer strasse 40 — [3]Alba Synchrotron, Barcelona, Spain — [4]Solaris synchrotron, Krakow, Poland — [5]INMA, Zaragoza, Spain

Three dimensional nanomagnetic systems, with novel and unconventional spin textures, represent an exciting platform to explore new magnetic phenomena for the development of more efficient, capable and multifunctional technologies. In particular, the 3D geometry is predicted to have a significant influence on the dynamics of magnetic domain walls through the introduction of curvature and torsion, where new physics and functionalities can be realised.

Here, we experimentally explore the influence of 3D geometry on the energetics of domain walls by introducing curvature using focused electron beam induced deposition. We probe the behaviour of DWs within 3D curved systems with soft x-ray magnetic microscopy, that allows us to directly observe the magnetic state and the domain walls, and determine their response to the application of magnetic fields . This insight into the control that can obtained via complex geometries will help pave the way to the next generation of 3D spintronic devices.

MA 50.2 Fri 9:45 POT 6

Geometry-induced effects in domain wall dynamics in stripes with spatially varying cross section — •Kostiantyn V. Yershov[1,2] and Denis D. Sheka[3] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine — [3]Taras Shevchenko National University of Kyiv, Ukraine

Here we study both analytically and numerically the influence of curvature and cross section deformation effects on the motion of a domain wall in curved stripes which corresponds to geometry of recent experiments [1]. We base our study on a phenomenological Landau–Lifshitz–Gilbert equations using collective variable approach based on a $q-\Phi$ model. We show that (i) curvature and nonzero gradient of cross-section deformation result in a modification of a ground state and can be interpreted as an effective magnetic field. (ii) The presence of a nonzero gradient of cross section deformation also results in a pinning potential for domain walls in addition to the curvature-induced potential [2]. In effective equations of motions the spatially varying cross section and curvature appear as a driving forces which can suppress or reinforce the action of each other. The eigenfrequency oscillations of domain wall in vicinity of the pinning potential is obtained as a function of curvature and cross section deformation and their gradients. All analytical predictions are well confirmed by full scale micromagnetic simulations. [1] L. Skoric et al, ACS Nano **16**, 8860 (2022); [2] K. V. Yershov et al, PRB **92**, 104412 (2015).

MA 50.3 Fri 10:00 POT 6

Domain wall tilt in thin CrOx/Co/Pt corrugated stripes — •Jose A. Fernandez-Roldan[1], Mikel Quintana[1,2], Shahrukh Shakeel[1], Oleksii Volkov[1], Oleksandr Pylypovskyi[1], Eduardo Sergio Oliveros-Mata[1], Florian Kronast[3], Mohamad-Assaad Mawass[3], Claas Abert[4], Dieter Suess[4], Denise Erb[1], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]CIC nanoGUNE BRTA, Donostia-San Sebastian, Spain — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [4]Physics of Functional Materials, University of Vienna, Vienna, Austria

Curvilinear magnetism is a flourishing field of interest for applications in flexible magnetoelectric devices, microrobots, sensors and nanoelectronics [1-2]. Curvilinear phenomena often result in magnetization patterning, symmetry breaks and Domain Wall (DW) pinning. However, these phenomena have remained so far unexplored in stripes. Here, spin-orbit torques allow the manipulation of DWs [3] with a low power consumption. A recent approach permits the estimation of Dzyaloshinskii-Moriya interaction from DW tilt in thin stripes [4]. Here we provide first results on 100 nm wide 2 nm thin corrugated CrOx/Co/Pt stripes with a mean curvature of 0.06 nm^{-1}. Our results open a perspective for the design of curvature-induced effects with application prospects in current challenges of nanoelectronics. [1] D. Makarov et al., Adv.Mater. 34(3), 2101758 (2022); [2] D. Sheka et al., Small 18, 2105219 (2022); [3] O. Pylypovskyi et al. Sci.Rep. 6, 23316 (2016); [4] O. M. Volkov et al., Phys.Rev.Appl. 15, 034038 (2021).

MA 50.4 Fri 10:15 POT 6

Get in Shape - Closed Magnetoelastic Domain Wall Loops in Antiferromagnets — •Bennet Karetta and Olena Gomonay — Johannes-Gutenberg Universität Mainz

Antiferromagnets are new candidates to be used as active spintronics elements as they are faster and more stable than the ferromagnets in current devices. However, their lack of a net magnetization introduces the challenge to manipulate the magnetic state. Recent studies suggested that the magnetoelastic coupling can be used for this task. Thus, understanding the interaction between strain and Néel vector is of high priority. We study the orientation in different antiferromagnetic domain walls which is influenced by magnetostriction. We show how the energy of the domain wall depends on its orientation on the antiferromagnet. Further, we apply the results to a system of a closed domain wall loops. The anisotropy of the energy significantly changes the shape of the closed loop to an anisotropic form. The exact shape is given by the type of domain wall and magnetoelastic coupling strength. For its determination we finally present a method to quantify the change of the domain wall shape from the zero magnetoelastic coupling case.

MA 50.5 Fri 10:30 POT 6

Magneto-Optic Effects and Domain Imaging in EuO film and 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 (FM) of 7 μB 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 the coercivity of hysteresis loops as well as magnetic domains in EuO film and in a EuO/3d-FM heterostructure. We synthesized EuO/Co heterostructure sample using molecular beam epitaxy on Nb:STO and observed the 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 using a Kerr microscope. To explore the temperature-dependent magneto-optic effects in EuO in the proximity of Co, we measured hysteresis at various temperatures below and above Tc. This study of proximity effect-induced changes in magnetic domains in EuO due to Co can provide insights into achieving room-temperature FM in EuO.

MA 50.6 Fri 10:45 POT 6

Electric field induced magnetic swicthing in spin-spiral multiferroics — Francesco Foggetti[1,2] and •Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genova, Italy — [2]Uppsala University, Sweden

Switching in magnetic materials gives rise to rich physical phenomena and lies at the heart of their technological applications. Although domain wall motion in ferro- and antiferromagnets has been studied, in spiral magnets it is still poorly understood despite 20 years of active research since the discovery of spiral multiferroics. The problem of the domain wall motion in a spiral magnet is a compelling one, the more so the magnetic domain walls in cycloidal spiral phase are also ferroelectric, thus enabling electric control of magnetism, i.e. domain wall motion under the action of an external electric field. Phase transition to a spiral phase leads to a formation of chiral domains with opposite spin rotation senses, that are separated by chiral domain walls. Spiral order breaks inversion symmetry and induces a ferroelectric polarization, whose sign is determined by the chirality of the domain. Thus the spiral order allows for the manipulation of spins via an external electric field. Here we study domain wall motion in magnets with spiral ground state, that are the most basic non-collinear magnets. We formulate a simplified variational model and derive the equation of motion for the domain wall driven by an external electric field. The results are corroborated with atomistic spin dynamics simulations. The results suggest a linear dependence of the wall speed on the external electric field, and a peculiar dependence on the system geometry and domain structure.

MA 50.7 Fri 11:00 POT 6

Visualisation of an 4f-antiferromagnetic domain pattern in multiferroic $Dy_{0.7}Tb_{0.3}FeO_3$ — •Yannik Zemp[1], Mads C. Weber[1,2], Ehsan Hassanpour[1,3], Thomas Lottermoser[1], Yusuke Tokunaga[4], Yasujiro Taguchi[5], Yoshinori Tokura[5,6], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich — [2]IMMM, Le Mans Université — [3]UDEM Inselspital, University of Bern — [4]Department of Advanced Materials Science, University of Tokyo — [5]RIKEN CEMS, Japan — [6]Department of Applied Physics, University of Tokyo

We visualize the antiferromagnetic (AFM) domain pattern of the 4f-rare-earth subsystem in $Dy_{0.7}Tb_{0.3}FeO_3$. To do so, we exploit the unique order-parameter interaction in the multiferroic phase of this material, where the magnetic rare-earth- and iron subsystems induce ferroelectricity. By magnetic-field cooling into the multiferroic phase, we force the 4f-rare-earth- and ferroelectric domain pattern to be identical. We can then access the former by imaging the latter using optical second harmonic generation, which is very sensitive to a breaking of inversion symmetry. The 4f-AFM domains form stripes with a thickness of several $10\,\mu m$ along the antiferromagnetic easy axis. As a consequence, the ferroelectric domains are forced to form energetically unfavourable head-to-head and tail-to-tail domain walls. Also, the domain pattern is very dissimilar to the weakly ferromagnetic bubble-domain structure of the iron sublattice that is present at higher temperatures. These observations show that the rare-earth system orders independently from the other magnetic- and electric influences.