Division of Magnetism
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

Lecture rooms HSZ 04, HSZ 401, HSZ 403, HSZ 101, POT 6; Poster P3 (CHE Foyer), Poster P2-EG (HSZ/EG)

MA-organised interdivisional symposia

Attosecond and coherent spins: New frontiers

SYAS 1.1	Mon	15:00–15:30	HSZ 02	**Ultrafast Coherent Spin-Lattice Interactions in Ferromagnets** — •Steven L. Johnson
SYAS 1.2	Mon	15:30–16:00	HSZ 02	**Ab-initio treatment of ultrafast spin-dynamics** — •Sangeeta Sharma
SYAS 1.3	Mon	16:00–16:30	HSZ 02	**Light-wave driven Spin Dynamics** — •Martin Schultze
SYAS 1.4	Mon	16:45–17:15	HSZ 02	**All-coherent subcycle switching of spins by THz near fields** — •Christoph Lange
SYAS 1.5	Mon	17:15–17:45	HSZ 02	**Ultrafast optically-induced spin transfer in ferromagnetic alloys** — •Stefan Mathias

Curvilinear condensed matter

SYCL 1.1	Fri	9:30–10:00	HSZ 02	**Topology and transport in nanostructures with curved geometries** — •Carmine Ortix
SYCL 1.2	Fri	10:00–10:30	HSZ 02	**Properties of domain walls and skyrmions in curved ferromagnets.** — •Volodymyr Kravchuk
SYCL 1.3	Fri	10:30–11:00	HSZ 02	**3D Mesoscopic Magnetic Architectures: Fabrication, Actuation & Imaging** — •Laura Heyderman
SYCL 1.4	Fri	11:15–11:45	HSZ 02	**3D nanostructures for superconductivity and magnetism** — •Oleksandr Dobrovolskiy
SYCL 1.5	Fri	11:45–12:15	HSZ 02	**Effect of Curvature on Topological Defects in Chiral Condensed and Soft Matter** — •Avadh Saxena

INNOMAG e.V. Dissertation Prize

Finalists session

MA 16.1	Mon	15:00–15:25	POT 6	**Spintronics with Terahertz Radiation: Probing and driving spins at highest frequencies** — •Tom S. Seifert
MA 16.2	Mon	15:25–15:50	POT 6	**Linear and nonlinear spin waves in nanoscale magnonic structures for data processing** — •Qi Wang
MA 16.3	Mon	15:50–16:15	POT 6	**Highly efficient domain wall motion in ferrimagnetic bi-layer systems at the angular momentum compensation temperature** — •Robin Bläsing
MA 16.4	Mon	16:15–16:40	POT 6	**Spin-orbit driven transport: Edelstein effect in Rashba systems and topological materials** — •Annika Johansson

MA-organised topical talks

MA 25.1	Tue	9:30–10:00	POT 6	**Emergent electromagnetic response of nanometer-sized spin textures** — •Max Hirschberger
MA 34.1	Wed	9:30–10:00	POT 6	**Anatomy of skyrmion-defect interactions and their impact on detection protocols** — •Samir Lounis
MA 36.1	Wed	15:00–15:30	HSZ 101	**2D Magnetic Materials** — •Alberto Morpurgo
MA 44.1	Thu	9:30–10:00	HSZ 101	**Vacuum Resonance States as Atomic-Scale Probes of Noncollinear Surface Magnetism** — •Anika Schlenhoff

PhD focus sessions (invited talks only)

Symposium on "Strange bedfellows — magnetism meets superconductivity"

MA 20.1	Tue	9:30–10:15	HSZ 04	**Magnetism and superconductivity: building new physics one atom at a time** — •Alexander Balatsky
MA 20.3	Tue	10:30–11:00	HSZ 04	**Yu-Shiba-Rusinov states of single magnetic atoms and nanostructures probed by scanning tunneling spectroscopy** — •Katharina J. Franke
MA 20.5	Tue	11:15–11:45	HSZ 04	**Majorana bound states in magnetic skyrmions** — •Jelena Klinovaja
MA 20.7	Tue	12:00–12:30	HSZ 04	**Orbital selective superconductivity in iron-based superconductors** — •Pengcheng Dai

Symposium on "Magnetism — a potential platform for Big Data?"

MA 35.1	Wed	15:00–15:30	HSZ 04	**Data Storage and Processing in the Cognitive Era** — •Giovanni Cherubini
MA 35.2	Wed	15:30–16:00	HSZ 04	**Brain-inspired approaches and ultrafast magnetism for Green ICT** — •Theo Rasing
MA 35.3	Wed	16:15–16:45	HSZ 04	**How good are spin waves for data processing?** — •Andrii Chumak
MA 35.4	Wed	16:45–17:15	HSZ 04	**Unconventional computing with stochastic magnetic tunnel junctions** — •Alice Mizrahi

MA-organised focus sessions (invited talks only)

Spin-charge interconversion

MA 10.1	Mon	15:00–15:30	HSZ 04	**SrTiO3-based 2-dimensional electron gases for ultralow power spintronics** — •Manuel Bibes
MA 10.5	Mon	17:15–17:45	HSZ 04	**Theory of spin-to-charge conversion in a topological oxide two-dimensional electron gas** — •Annika Johansson
MA 10.3	Mon	16:00–16:30	HSZ 04	**Spin-charge interconversion in graphene/TMD Van der Waals heterostructures** — •Bart Van Wees
MA 10.4	Mon	16:45–17:15	HSZ 04	**Ferroelectric control of the spin-to-charge conversion in the ferroelectric Rashba semiconductor GeTe** — •Christian Rinaldi
MA 10.2	Mon	15:30–16:00	HSZ 04	**Spin-to-charge current conversion for logic devices** — •Felix Casanova
MA 10.6	Mon	17:45–18:15	HSZ 04	**Nonlinear magnetoresistance from surface states of a topological insulator** — •Giovanni Vignale

Magnon polarons — magnon-phonon coupling and spin transport

MA 29.1	Wed	9:30–10:00	HSZ 04	**Magnon-polaron transport in magnetic insulators** — •Benedetta Flebus
MA 29.2	Wed	10:00–10:30	HSZ 04	**Spin-phonon coupling in non-local spin transport through magnetic insulators** — •Rembert Duine
MA 29.3	Wed	10:30–11:00	HSZ 04	**Anisotropic transport of spontaneously accumulated magneto-elastic bosons in yttrium iron garnet films** — •Alexander A. Serga
MA 29.5	Wed	11:15–11:45	HSZ 04	**Boltzmann approach to the longitudinal spin Seebeck effect** — •Rico Schmidt

MA 29.6	Wed	11:45–12:15	HSZ 04	**Magnon-polaron excitations in the noncollinear antiferromagnet Mn_3Ge** — •Aleksandr Sukhanov
MA 29.7	Wed	12:15–12:45	HSZ 04	**Magnon-Polarons in different flavors: (anti)ferromagnetic to topological** — •Akashdeep Kamra

Higher-order magnetic interactions — implications in 2D and 3D magnetism

MA 43.1	Thu	9:30–10:00	HSZ 04	**Magnetic vortices, skyrmions, and hedgehogs stabilized by long-range multiple-spin interactions** — •Yukitoshi Motome
MA 43.2	Thu	10:00–10:30	HSZ 04	**Formation of spin-hedgehog lattices and giant topological transport properties in chiral magnets** — •Naoya Kanazawa
MA 43.3	Thu	10:30–11:00	HSZ 04	**Topological-chiral magnetic interactions driven by emergent orbital magnetism** — •S. Grytsiuk
MA 43.5	Thu	11:30–12:00	HSZ 04	**How to understand the physics of complex spin structures** — •Matthias Bode
MA 49.1	Thu	15:00–15:30	HSZ 04	**The role of itinerant electrons and higher order magnetic interactions among fluctuating local moments in producing complex magnetic phase diagrams.** — •Christopher Patrick

Joint symposia

Invited talks of the joint symposium SYSD

See SYSD for the full program of the symposium.

SYSD 1.1	Mon	9:30– 9:55	HSZ 02	**Disentangling transport in topological insulator thin films down to the nanoscale** — •Felix Lüpke
SYSD 1.2	Mon	9:55–10:20	HSZ 02	**Spintronics with Terahertz Radiation: Probing and driving spins at highest frequencies** — •Tom Sebastian Seifert
SYSD 1.3	Mon	10:20–10:45	HSZ 02	**Non-radiative voltage losses in organic solar cells** — •Johannes Benduhn
SYSD 1.4	Mon	10:45–11:10	HSZ 02	**Multivalent ions for tuning the phase behaviour of protein solutions** — •Olga Matsarskaia
SYSD 1.5	Mon	11:10–11:35	HSZ 02	**Network Dynamics under Constraints** — •Malte Schröder
SYSD 1.6	Mon	11:35–12:00	HSZ 02	**Exciton spectroscopy of van der Waals heterostructures** — •Philipp Nagler

Invited talks of the joint symposium SYAS

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SYAS 1.3	Mon	16:00–16:30	HSZ 02	**Light-wave driven Spin Dynamics** — •Martin Schultze
SYAS 1.4	Mon	16:45–17:15	HSZ 02	**All-coherent subcycle switching of spins by THz near fields** — •Christoph Lange
SYAS 1.5	Mon	17:15–17:45	HSZ 02	**Ultrafast optically-induced spin transfer in ferromagnetic alloys** — •Stefan Mathias

Invited talks of the joint symposium SYWH

See SYWH for the full program of the symposium.

SYWH 1.1	Wed	15:00–15:30	HSZ 02	**Engineering 2D materials with a twist** — •Cory Dean
SYWH 1.2	Wed	15:30–16:00	HSZ 02	**Flat Bands and Correlated Electronic States in Two Dimensional Atomic Crystals** — •Eva Y. Andrei
SYWH 1.3	Wed	16:00–16:30	HSZ 02	**Lightwave electronics and valleytronics in van der Waals layered materials** — •Rupert Huber
SYWH 1.4	Wed	16:30–17:00	HSZ 02	**Interaction and Topological Effects in Atomically Thin Two-dimensional Materials** — •Steven G. Louie

SYWH 1.5	Wed	17:00–17:30	HSZ 02	**Excitons in 2D Semiconductors and Heterostructures** — •Alexander Högele

Invited talks of the joint symposium SYED

See SYED for the full program of the symposium.

SYED 1.1	Thu	9:30–10:00	HSZ 01	**Ultrafast electron dynamics at laser-irradiated surfaces** — •Baerbel Rethfeld
SYED 1.2	Thu	10:00–10:30	HSZ 01	**Unraveling Momentum-Dependent Electron-Phonon Coupling and its Role in the Origin of Charge Density Wave Phases** — •Bradley Siwick
SYED 1.3	Thu	10:30–11:00	HSZ 01	**Light MATTERs!!!** — •Hrvoje Petek
SYED 1.4	Thu	11:15–11:45	HSZ 01	**Quantum localization and delocalization of charge carriers in molecular organic crystals** — •Jochen Blumberger
SYED 1.5	Thu	11:45–12:15	HSZ 01	**Single-Atom Catalysis (SAC): How Structure Influences Reactivity** — •Gareth Parkinson

Invited talks of the joint symposium SYES

See SYES for the full program of the symposium.

SYES 1.1	Thu	9:30–10:00	HSZ 02	**Understanding the physical variables driving mechanosensing** — •Pere Roca-Cusachs
SYES 1.2	Thu	10:00–10:30	HSZ 02	**Mechanics of life: Cellular forces and mechanics far from thermodynamic equilibrium** — •Timo Betz
SYES 1.3	Thu	10:30–11:00	HSZ 02	**A hydrodynamic approach to collective cell migration in epithelial tissues** — •Jaume Casademunt
SYES 1.4	Thu	11:15–11:45	HSZ 02	**The spindle is a composite of two permeating polar gels** — •Jan Brugues
SYES 1.5	Thu	11:45–12:15	HSZ 02	**Adding magnetic properties to epitaxial graphene** — •Rodolfo Miranda
SYES 2.1	Thu	15:00–15:30	HSZ 01	**Interactions in assemblies of surface-mounted magnetic molecules** — •Wolfgang Kuch
SYES 2.2	Thu	15:30–16:00	HSZ 01	**Towards phononic circuits based o optomechanics** — •Clivia M. Sotomayor-Torres
SYES 2.3	Thu	16:00–16:30	HSZ 01	**Optical properties of 2D materials and heterostructures** — •Janina Maultzsch
SYES 2.4	Thu	16:45–17:15	HSZ 01	**Bringing nanophotonics to the atomic scale** — •Javier Aizpurua
SYES 2.5	Thu	17:15–17:45	HSZ 01	**Infrared signatures of the coupling between vibrational and plasmonic excitations** — •Annemarie Pucci

Invited talks of the joint symposium SYCL

See SYCL for the full program of the symposium.

SYCL 1.1	Fri	9:30–10:00	HSZ 02	**Topology and transport in nanostructures with curved geometries** — •Carmine Ortix
SYCL 1.2	Fri	10:00–10:30	HSZ 02	**Properties of domain walls and skyrmions in curved ferromagnets.** — •Volodymyr Kravchuk
SYCL 1.3	Fri	10:30–11:00	HSZ 02	**3D Mesoscopic Magnetic Architectures: Fabrication, Actuation & Imaging** — •Laura Heyderman
SYCL 1.4	Fri	11:15–11:45	HSZ 02	**3D nanostructures for superconductivity and magnetism** — •Oleksandr Dobrovolskiy
SYCL 1.5	Fri	11:45–12:15	HSZ 02	**Effect of Curvature on Topological Defects in Chiral Condensed and Soft Matter** — •Avadh Saxena

Sessions

MA 1.1–1.12	Mon	9:30–12:45	HSZ 04	**Computational Magnetism I**

MA 2.1–2.11	Mon	9:30–12:30	HSZ 101	**Ultrafast Magnetization I**
MA 3.1–3.13	Mon	9:30–13:00	HSZ 201	**Complex Oxides: Bulk Properties (jointly with DS, HL, KFM, MA, O) (joint session TT/MA/HL)**
MA 4.1–4.13	Mon	9:30–13:00	HSZ 304	**Frustrated Magnets - General 1 (joint session TT/MA)**
MA 5.1–5.15	Mon	9:30–13:15	HSZ 401	**Cooperative Phenomena and Phase Transitions (joint session MA/TT)**
MA 6.1–6.7	Mon	9:30–11:15	HSZ 403	**Micro- and Nanostructured Materials (joint session MA/TT)**
MA 7.1–7.8	Mon	9:30–11:30	POT 6	**Topological Phenomena (joint session MA/TT)**
MA 8.1–8.11	Mon	10:30–13:15	TRE Phy	**Ultrafast Electron Dynamics I: Surfaces and Interfaces (joint session O/MA)**
MA 9.1–9.7	Mon	11:30–13:15	POT 6	**Weyl Semimetals**
MA 10.1–10.6	Mon	15:00–18:15	HSZ 04	**Focus Session: Spin-Charge Interconversion (joint session MA/HL)**
MA 11.1–11.8	Mon	15:00–17:00	HSZ 101	**Bio- and Molecular Magnetism (joint session MA/CPP)**
MA 12.1–12.7	Mon	15:00–17:40	HSZ 105	**Multiferroics (joint session KFM/MA)**
MA 13.1–13.4	Mon	15:00–16:00	HSZ 304	**Frustrated Magnets - General 2 (joint session TT/MA)**
MA 14.1–14.12	Mon	15:00–18:15	HSZ 401	**General Spintronics**
MA 15.1–15.6	Mon	15:00–16:30	HSZ 403	**Computational Magnetism II**
MA 16.1–16.4	Mon	15:00–16:40	POT 6	**INNOMAG e. V. Dissertation Prize**
MA 17.1–17.8	Mon	16:15–18:15	HSZ 304	**Skyrmions (jointly with MA, O) (joint session TT/MA)**
MA 18.1–18.8	Mon	16:45–18:45	HSZ 403	**Magnetic Particles and Clusters**
MA 19.1–19.7	Mon	17:15–19:00	HSZ 101	**Characterization and Instrumentation**
MA 20.1–20.9	Tue	9:30–13:00	HSZ 04	**PhD Focus Session: Symposium on "Strange Bedfellows – Magnetism Meets Superconductivity" (joint session MA/AKjDPG)**
MA 21.1–21.14	Tue	9:30–13:15	HSZ 101	**Ultrafast Magnetization II**
MA 22.1–22.13	Tue	9:30–13:00	HSZ 304	**Frustrated Magnets - Spin Liquids 1 (joint session TT/MA)**
MA 23.1–23.14	Tue	9:30–13:15	HSZ 401	**Functional Antiferromagnetism**
MA 24.1–24.9	Tue	9:30–11:45	HSZ 403	**Magnetic Heusler Compounds**
MA 25.1–25.12	Tue	9:30–13:00	POT 6	**Skyrmions I (joint session MA/TT)**
MA 26.1–26.10	Tue	10:30–13:30	WIL B321	**Ultrafast Electron Dynamics II (joint session O/MA)**
MA 27.1–27.7	Tue	14:00–15:45	HSZ 02	**Complex Oxides: Surfaces and Interfaces (jointly with DS, HL, KFM, MA, O) (joint session TT/MA/HL)**
MA 28.1–28.5	Tue	14:00–15:15	HSZ 304	**Frustrated Magnets - Spin Liquids 2 (joint session TT/MA)**
MA 29.1–29.8	Wed	9:30–13:00	HSZ 04	**Focus Session: Magnon Polarons – Magnon-Phonon Coupling and Spin Transport (joint session MA/HL)**
MA 30.1–30.12	Wed	9:30–12:45	HSZ 101	**Ultrafast Magnetization III**
MA 31.1–31.12	Wed	9:30–13:00	HSZ 304	**Frustrated Magnets - Strong Spin-Orbit Coupling 1 (joint session TT/MA)**
MA 32.1–32.10	Wed	9:30–12:15	HSZ 401	**Multiferroics and Magnetoelectric Coupling I (joint session MA/KFM)**
MA 33.1–33.10	Wed	9:30–12:15	HSZ 403	**Correlation Theory I**
MA 34.1–34.12	Wed	9:30–13:00	POT 6	**Skyrmions II (joint session MA/TT)**
MA 35.1–35.4	Wed	15:00–17:15	HSZ 04	**PhD Focus Session: Symposium on "Magnetism – A Potential Platform for Big Data?" (joint session MA/AKjDPG/O)**
MA 36.1–36.10	Wed	15:00–18:00	HSZ 101	**Spin-Dependent 2D Phenomena**
MA 37.1–37.10	Wed	15:00–17:45	HSZ 304	**Frustrated Magnets - Strong Spin-Orbit Coupling 2 (joint session TT/MA)**
MA 38.1–38.8	Wed	15:00–17:00	HSZ 401	**Multiferroics and Magnetoelectric Coupling II (joint session MA/KFM)**
MA 39.1–39.4	Wed	15:00–16:00	HSZ 403	**Correlation Theory II**
MA 40.1–40.13	Wed	15:00–18:30	POT 6	**Skyrmions III (joint session MA/TT)**
MA 41.1–41.9	Wed	15:00–18:20	TOE 317	**Ferroics - Domains and Domain Walls (joint session KFM/MA)**
MA 42.1–42.56	Wed	15:00–18:00	P3	**Posters Magnetism I**
MA 43.1–43.9	Thu	9:30–13:00	HSZ 04	**Focus Session: Higher-Order Magnetic Interactions – Implications in 2D and 3D Magnetism I**
MA 44.1–44.8	Thu	9:30–12:00	HSZ 101	**Surface Magnetism (joint session MA/O)**
MA 45.1–45.13	Thu	9:30–13:00	HSZ 401	**Magnonics I**
MA 46.1–46.13	Thu	9:30–13:00	HSZ 403	**Spin: Transport, Orbitronics and Hall Effects I**

MA 47.1–47.7	Thu	9:30–11:15	POT 6	**Skyrmions IV (joint session MA/TT)**
MA 48.1–48.9	Thu	10:30–12:45	WIL B321	**Ultrafast Electron Dynamics III (joint session O/MA)**
MA 49.1–49.7	Thu	15:00–17:00	HSZ 04	**Focus Session: Higher-Order Magnetic Interactions – Implications in 2D and 3D Magnetism II**
MA 50.1–50.9	Thu	15:00–17:30	HSZ 101	**Permanent Magnets**
MA 51.1–51.10	Thu	15:00–17:45	HSZ 201	**Ultrafast Dynamics of Light-Driven Systems (joint session TT/MA)**
MA 52.1–52.10	Thu	15:00–18:00	HSZ 304	**Quantum Magnets and Molecular Magnets (joint session TT/MA)**
MA 53.1–53.7	Thu	15:00–16:45	HSZ 401	**Magnonics II**
MA 54.1–54.10	Thu	15:00–17:45	HSZ 403	**Spin: Transport, Orbitronics and Hall Effects II**
MA 55.1–55.8	Thu	15:00–17:15	POT 6	**Non-Skyrmionic Magnetic Textures**
MA 56.1–56.12	Thu	15:00–18:00	WIL A317	**Surface Magnetism I (joint session O/MA)**
MA 57.1–57.55	Thu	15:00–18:00	P3	**Posters Magnetism II**
MA 58	Thu	18:00–19:00	POT 6	**General Assembly of the Division of Magnetism**
MA 59.1–59.50	Fri	9:00–12:00	P2/EG	**Posters Magnetism III**
MA 60.1–60.13	Fri	9:30–13:00	HSZ 04	**Magnetic Coupling and Anisotropy in Thin Films (joint session MA/DS)**
MA 61.1–61.15	Fri	9:30–13:15	HSZ 101	**Caloric Effects**
MA 62.1–62.8	Fri	9:30–11:30	HSZ 401	**Disodered Magnetic Materials**
MA 63.1–63.13	Fri	9:30–13:00	HSZ 403	**Spin: Transport, Orbitronics and Hall Effects III**
MA 64.1–64.13	Fri	10:30–13:45	GER 38	**Surface Magnetism II (joint session O/MA)**

General assembly of the Division of Magnetism

Thursday 18.00 – 19.00 POT 6
All members of the Division of Magnetism are invited to attend!

MA 1: Computational Magnetism I

Time: Monday 9:30–12:45 Location: HSZ 04

MA 1.1 Mon 9:30 HSZ 04

Accelerated evaluation of thermal conductivity via machine learning: A case study of two-dimensional (2D) BN — •Yixuan Zhang, Chen Shen, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

Accurate density functional theory (DFT) calculations to evaluate the anharmonic effect are demanding, as accurate force constants from DFT up to the third or even higher orders are needed. In this work, using the recently developed machine learning technique, we obtained accurate force constants by learning over a limited number of configurations and demonstrated that the thermal conductivity can be evaluated accurately. The interatomic potential is developed using the GAP model, and the resulting forces are fed into Alamode to evaluate the thermal conductivity. The configurations for training were automatically selected using the active learning method, which enables future on-the-fly calculations. For 2D BN sheets, it is demonstrated that the final training set can be reduced to 123 out of total 867 geometries, and the resulting thermal conductivity is only slightly deviated from the values obtained via explicit DFT calculations. It is suspected that the method can be applied to other 2D/3D compounds where the computational effort required can be reduced by one order of magnitude.

MA 1.2 Mon 9:45 HSZ 04

High-throughput Screening for Novel MAB Phases — •Chen Shen, Qiang Gao, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

The MAB phases are transition metal (M) borides with layered structures, which display a spectrum of intriguing magnetocaloric, mechanical and corrosion properties. In this work, based on density functional theory (DFT) calculations carried out in a high-throughput (HTP) way, we investigated systematically the stabilities and magnetic properties of six classes of MAB phases, e.g., MAB, M_2AB_2, $M_3A_2B_2$,M_3AB_4, M_4AB_4 and M_4AB_6, and three competitive phases such as M_5AB_2, $M_4A_3B_2$ and $M_3A_2B_2$, where M = Cr, Mn, Fe, Co and Ni; A = an arbitrary element from Li to Bi without inert gas and 4f rare-earth elements. Based on the thermodynamic phase diagram, it is predicted that there are tens of unreported MAB compounds which are stable. Moreover, it is found that several MAB compounds are promising permanent magnets with significant magnetocrystalline anisotropy (MAE) and sizable magnetization. For instance, the MAE of Mn_2PtB_2 is as large as 20.27 MJ/m^3. We believe such compounds are promising for future applications as functional magnetic materials.

MA 1.3 Mon 10:00 HSZ 04

Impact of the magnetic structure on the phase stability and functional properties of binary and ternary Mn alloys — •Ingo Opahle, Nuno Fortunato, Harish K. Singh, Qiang Gao, Oliver Gutfleisch, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

Mn alloys are of interest for hard magnetic, magnetocaloric and spintronics applications. The magnetic structure of Mn alloys can be complex, which makes computational high-throughput predictions of novel Mn based functional materials highly demanding.

We use high-throughput density functional calculations to determine the magnetic ground state of known compounds in several binary and ternary Mn alloy systems. Initial spin structures are obtained by algorithms based on maximal magnetic subgroups and antiferromagnetic coupling of sublattices. We show that the magnetic structure can have a strong impact on the calculated phase stability. For binary alloys of Mn with Ir, Pt and Au the formation energy for the ground state is up to 250 meV/atom lower compared to calculations with an assumed ferromagnetic structure. Phase diagrams assuming a ferromagnetic structure are unreliable for these systems and can not be used to identify important magnetic materials like Mn_3Ir used in exchange biased films for data storage or the spin-orbit-torque compound Mn_2Au.

Based on the magnetic ground state phase diagrams we performed structure type searches and discuss potentially new stable binary phases. Further, the impact of the magnetic structure on functional properties of Mn alloys is illustrated at hand of a few examples.

MA 1.4 Mon 10:15 HSZ 04

Electric field control of magnetism without currents: from experiments to ab-initio spectroscopy calculations. — •Eszter Simon, Alberto Marmodoro, Sergey Mankovsky, and Hubert Ebert — Department Chemie, Ludwig-Maximilians-Universität München

Recent x-ray magnetic dichroism (XMCD) experiments [1-3] have shown that the magnetic properties of an ultra thin Pt layer can be controlled by application of an electric field across the interface with a ferromagnetic substrate and through an insulating layer that prevents actual charge transport. We discuss ab-initio investigations of this experimental setup by means of a simple extension of the Korringa-Kohn-Rostoker method [3]. Our all-electron, fully relativistic implementation of the 2D TB-KKR scheme for semi-infinite systems allows to gain insight into the role of different lattice terminations in connection with spin-orbit coupling effects, to evaluate the role of dielectric/capping layers, and to cross-compare out-of-equilibrium results due to the applied finite perturbation in terms of ground state properties and theoretical spectroscopy simulations.

[1] F.Matsukura et. al., Nat.Nanotech **10**, 209 (2015). [2] S.Miwa et al., Nat.Comm. **8**, 15848. (2017). [3] K. Yamada et al., Phys. Rev. Lett. **120**, 157203 (2018).

MA 1.5 Mon 10:30 HSZ 04

Electric field control of magnetism through transverse currents: first-principles calculations on XAS/XMCD experiments. — Sergey Mankovsky, •Alberto Marmodoro, Eszter Simon, and Hubert Ebert — Department Chemie, Ludwig-Maximilians-Universität München

Recent x-ray magnetic dichroism spectroscopy (XMCD) experiments have investigated a variety of electric field-controlled magnetism scenarios [1-3]. We consider a 2D Co/Pt heterostructure, studied in various geometries, under the influence of an applied electric field parallel to the interface and also to the equilibrium magnetization direction. This setup has been reported to produce an additional, perpendicular out-of-plane magnetization contribution, proportional to the current density and detectable through variation in the absorption cross-section for circularly polarized x-ray at the Co $L_{2,3}$ edges [3]. We investigate this effect by means of first-principles linear response calculations, performed at a fully relativistic level using the Korringa-Kohn-Rostoker method based on DFT. The scheme allows us to assess different physical mechanisms behind the experimental observation, to explore the impact of sample thickness and surface/interface effects, and study effects of spin-orbit torque, spin accumulation and to cross-compare ab-initio results with calculated XMCD spectra.

[1] R.Kukreja et al., PRL **115**, 096601 (2015). [2] K. T. Yamada et al., PRL **120**, 157203 (2018). [3] C.Stamm et al., PRB **100**, 024426 (2019).

MA 1.6 Mon 10:45 HSZ 04

Thermodynamics of the S=1/2 Pyrochlore Antiferromagnet — •Robin Schaefer, David Luitz, and Imre Hagymási — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Studying three-dimensional frustrated quantum magnets is a challenging problem in general. Here we use several complementary techniques to study the high temperature behavior of the low spin pyrochlore quantum antiferromagnet: DMRG and quantum typicality yield exact results for small systems.

In order to test the stability of the features in the specific heat in the thermodynamic limit, we use the numerical linked cluster expansion, a systematic high temperature series expansion.

Rather than the usual approach based on clusters composed of single spins, we use physically motivated clusters of complete tetrahedra (i.e. complete unit cells), effectively allowing to access much higher orders of the expansion than otherwise possible. This combination of methods yields consistent results on the location of the high temperature peak of the specific heat.

15 min. break.

MA 1.7 Mon 11:15 HSZ 04

Robust first-principles scheme for extracting exchange interactions from full-potential electronic structure calculations — •Vladislav Borisov[1], Yaroslav O. Kvashnin[1], Pa-

trik Thunström[1], Anders Bergman[1], Anna Delin[3], Manuel Pereiro[1], Erik Sjöqvist[1], Danny Thonig[2], and Olle Eriksson[1,2] — [1]Department of Physics and Astronomy, Uppsala University, 75120 Uppsala, Sweden — [2]School of Science and Technology, Örebro University, 70182 Örebro, Sweden — [3]Department of Applied Physics, School of Engineering Sciences, KTH, Kista, Sweden

The design and optimization of magnetic materials can be done efficiently using first-principles electronic structure methods that allow to determine the microscopic mechanisms behind exchange interactions, which drive a particular magnetic behavior. The critical part of this approach is the mapping of the original electronic system onto a Heisenberg spin model. This requires the definition of a local projection for each magnetic atom, which may influence the calculated exchange interactions. In order to circumvent this problem, we propose a robust projection scheme within the RSPt full-potential electronic structure code for a reliable calculation of the magnetic exchange and demonstrate its performance for a few representative systems, including 3d and 4f metals, AFM insulators and low-dimensional systems. In the latter case, the inversion-symmetry breaking and spin-orbit coupling give rise to non-collinear magnetic textures, due to the Dzyaloshinskii-Moriya or higher-order interactions that can be analyzed using the proposed formalism.

MA 1.8 Mon 11:30 HSZ 04

Dzyaloshinskii-Moriya interaction enhanced reorientation in Fe_2W — •Balázs Nagyfalusi[1], László Udvardi[1,2], László Szunyogh[1,2], and Levente Rózsa[3] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary — [2]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budapest, Hungary — [3]Universität Konstanz, Konstanz, Germany

The magnetic ground state of an Fe bilayer on W(110) substrate is a normal-to-plane alignment which on higher temperatures turns into the $(1\bar{1}0)$ in-plane direction. We investigated this phenomenon with metadynamics Monte Carlo simulations[1] based on a classical Heisenberg model, and found that the neglection the antisymmetric part of the exchange tensor, i.e. the Dzyaloshinskii-Moriya interaction the reoriention no longer occurs. The simulation has been performed using exchange tensors and anisotropy parameters obtained from ab-initio calculations.

1. B. Nagyfalusi *et al.* https://arxiv.org/abs/1907.03616

MA 1.9 Mon 11:45 HSZ 04

Ab-initio study of phase transitions in Fe100-xAlx alloys — •Vasily Buchelnikov, Mariya Matyunina, and Mikhail Zagrebin — Chelyabinsk State University, Chelyabinsk, Russia

Fe-Al-based functional materials are perspective for industrial application due to the unique combination of properties such as high strength, corrosion stability, low density, and low cost. It would be interesting to estimate structural and magnetic phase transition temperatures in the most questionable area of 10-40 at.% of Fe-Al with different structures. In this work, based on structural and magnetic phase transition temperatures estimated theoretically from the first principles, the concentration phase diagram for Fe100-xAlx (15.625<x<31.25 at.%) was plotted. Structural phase transition temperatures for the experimentally observed crystal structures were obtained from the structural optimization. It is shown that for x=28.125 at.% L12-like phase with slight distortions is energetically favorable. The ground state energy and magnetic moments of Fe75Al25 with different structures were calculated within GGA and GGA+U approaches. It is shown that in the case of GGA+U approximation, L12 phase becomes more stable compared with D03. The Curie temperatures were estimated from mean field approximation and Monte Carlo simulations using ab initio calculated exchange coupling constants. Both structural and magnetic phase transition temperatures are found in qualitative agreement with the experiment. Depending on Al concentration, five different sequences of phase transitions are observed in the phase diagram.

MA 1.10 Mon 12:00 HSZ 04

Variational Monte Carlo approach for the dynamical spectra of frustrated spin systems — •Francesco Ferrari[1,2] and Federico Becca[3] — [1]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Frankfurt Am Main (Germany) — [2]SISSA-ISAS, International School for Advanced Studies, Trieste (Italy) — [3]Università degli Studi di Trieste, Trieste (Italy)

Inelastic neutron-scattering experiments provide fundamental insights into the behavior of magnetic systems and constitute the method of choice for the detection of the spin-liquid phase in candidate materials. However, the theoretical and numerical calculation of dynamical spectra, which are directly measured in neutron-scattering experiments, represents a formidable task in the context of frustrated magnetism. In our work, we employ an efficient variational Monte Carlo scheme to compute the spin dynamical structure factor of frustrated spin models.

We present our numerical results for the dynamical spectra of the antiferromagnetic J1-J2 Heisenberg model on the triangular lattice [1]. In the Heisenberg limit (J2=0), where the system is magnetically ordered, our variational spectra display a well-defined magnon branch, in contrast with spin-wave predictions of spontaneous magnon decay, and in agreement with recent DMRG calculations and inelastic neutron-scattering experiments on Ba3CoSb2O9. When frustration is included, the system undergoes a phase transition to a spin-liquid phase, whose spectral features indicate the presence of fractionalized spinon excitations, and highlight the important role played by gauge fluctuations.

[1] F. Ferrari and F. Becca, Phys. Rev. X 9, 031026 (2019).

MA 1.11 Mon 12:15 HSZ 04

Quantum effects in thermally activated domain wall switching in ferromagnets. — •Grzegorz Kwiatkowski[1] and Pavel F. Bessarab[1,2] — [1]University of Iceland, Reykjavík, Iceland — [2]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

Most widely used data storage technologies are based on nanoscale magnetic structures [1]. In order to improve both memory retention and energy efficient writability one needs to increase stability of magnetic samples without changing the energy barrier. Therefore, it is vital to optimise the preexponential factor in the Arrhenius law, which requires one to properly study the effect of internal degrees of freedom on thermal switching pocesses [2,3]. We present analytic estimation of rate of escape for domain wall switching in 3D samples with focus on how results scale with internal parameters and sample size. Since minimum excitation energy for high frequency magnon modes is larger than average energy of thermal fluctuations, we employ Bose-Einstein statistics, which leads to nontrivial temperature dependencies of the preexponential factor. Our results open up new possibilities for enhancing stability of magnetic structures by entropic effects.

This work was funded by the Icelandic Reseach Fund (Grant No. 184949-052) and Alexander von Humboldt Foundation.

[1] W. A. Challener et al. Nat. Photon. volume 3 (2009)
[2] P. F. Bessarab et al. Phys. Rev. Lett. 110.2 (2013)
[3] G. Fiedler et al. J. Appl. Phys. 111 (2012)

MA 1.12 Mon 12:30 HSZ 04

Dynamical structure factors of dynamical quantum simulators — •Maria Laura Baez[1,2], Marcel Goihl[2], Jonas Haferkamp[2], Juan Bermejo-Vega[2,3], Marek Gluza[2], and Jens Eisert[2,4] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Dahlem Center for Complex Quantum Systems, Berlin, Germany — [3]Institute for Theoretical and Computational Physics, Granada, Spain — [4]Helmholtz-Zentrum Berlin für Materialen und Energie, Germany

The dynamical structure factor is one of the experimental quantities crucial in scrutinizing the validity of the microscopic description of strongly correlated systems. Despite its long-standing importance, it is exceedingly difficult in generic cases to numerically calculate it, ensuring that the necessary approximations involved yield a correct result. We discuss in what way results on the hardness of classically tracking time evolution under local Hamiltonians are precisely inherited by dynamical structure factors; and hence offer in the same way the potential computational capabilities as dynamical quantum simulators do. Furthermore, we improve upon a novel, readily available, measurement setup allowing for the determination of the dynamical structure factor in different architectures, including arrays of ultra-cold atoms, trapped ions, Rydberg atoms, and superconducting qubits. Our results suggest that quantum simulations employing near-term quantum devices allow for the observation of dynamical structure factors of correlated quantum matter in the presence of experimental imperfections, for larger system sizes than what is achievable by classical simulation.

MA 2: Ultrafast Magnetization I

Time: Monday 9:30–12:30 Location: HSZ 101

MA 2.1 Mon 9:30 HSZ 101

Theory of out-of-equilibrium electron and phonon dynamics after laser excitation in metals — •Ulrike Ritzmann[1,2,3], Peter M. Oppeneer[1,3], and Pablo Maldonado[3] — [1]Fachbereich Physik, Freie Universität Berlin, Berlin, Germany — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany — [3]Department of Physics and Astronomy, Uppsala University, Uppsala, Germany

Ultrafast magnetization phenomena are often described using the two-temperature model (2TM) to compute the electron and phonon dynamics after laser excitation. This model assumes that both subsystems are locally at thermal equilibrium. However, recent experiments show that this description is not sufficient to describe the out-of-equilibrium dynamics on ultrashort timescales. Here, we present a parameter-free microscopic out-of-equilibrium model to describe the ultrafast laser- induced system dynamics in various nonmagnetic and magnetic metals such as gold, aluminium, iron, nickel and cobalt. We report strong deviations from the 2TM on the picosecond timescale for all materials studied. Furthermore, we demonstrate the importance of the mode-dependence of the electron-phonon coupling for the relaxation process and reveal the significance of this channel in the lattice equilibration. The computed new behavior demonstrates that phonon-mode dependent dynamics have to be considered in the ps time range in order to describe properly the lattice heating process and the subsequent dynamics of the whole system.

MA 2.2 Mon 9:45 HSZ 101

Ultrafast spin momentum transfer in noncollinear spin valves — •Pavel Baláž[1], Karel Carva[1], Maciej Zwierzycki[2], Pablo Maldonado[3], and Peter M. Oppeneer[3] — [1]Charles University, Faculty of Mathematics and Physics, Department of Condensed Matter Physics, Ke Karlovu 5, CZ 121 16 Prague, Czech Republic — [2]Institute of Molecular Physics, Polish Academy of Sciences, Smoluchowskiego 17, 60-179 Poznań, Poland — [3]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden

Ultrafast demagnetization of metallic thin films induced by a femtosecond laser pulse is a well-known phenomenon studied since 1996. One of the possible mechanisms is superdiffusive spin-dependent transport [1] of hot electrons excited by the pump laser from the localized *d* band to the *sp* one above the Fermi level. Here, we generalize this model for the case of a magnetic multilayer with noncollinear magnetizations [2]. The spin-dependent transport through the interfaces between the layers is described by energy-dependent reflections and transmissions calculated ab initio using the wave function matching method [3]. A substantial effect of spin filtering and of non-collinear magnetic configuration on ultrafast demagnetization and spin transfer torque is predicted for Al(3nm)/Ni(5nm)/Ru(2nm)/Fe(4nm)/Ru(5nm) spin valve. [1] M. Battiato et al., Phys. Rev. Lett. 105, 027203 (2010). [2] P. Baláž et al., J. Phys.: Cond. Matter 30, 115801 (2018). [3] M. Zwierzycki et al., Phys. Rev. B 71, 064420 (2005).

MA 2.3 Mon 10:00 HSZ 101

Ultrafast magnetization dynamics of ferromagnets on thin metal films — •Jonas Hoefer, Martin Stiehl, Christopher Seibel, Laura Scheuer, Simon Häuser, Sebastian T. Weber, Sanjay Ashok, Philipp Pirro, Burkhard Hillebrands, Benjamin Stadtmüller, Bärbel Rethfeld, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Strasse 46, 67663 Kaiserslautern, Germany

After the first observation of the ultrafast demagnetization process of ferromagnetic thin films, huge efforts were devoted to reveal the microscopic mechanism governing the ultrafast optically induced loss of magnetic order in ferromagnetic materials. It was soon realized that spin transport from a ferromagnetic into a non-magnetic metal can severely increase the speed of demagnetization of magnetic materials. So far, experimental studies focused on bulk-like non-magnetic thin films acting as a sink for the injected spins. In our study, we particular address the correlation between the demagnetization dynamics of a thin magnetic film and the thickness of a non-magnetic gold film underneath. Using time-resolved all-optical pump-probe MOKE experiments, we investigated the demagnetization time of a permalloy/gold bilayer systems for various Au film thicknesses. We find significantly longer demagnetization times for thin Au thicknesses compared to bulk-like Au films. These results will be discussed via theoretical model simulations describing the non-equilibrium dynamics of the optically excited spin carriers and their coupling through the interface.

MA 2.4 Mon 10:15 HSZ 101

Photon energy dependent fs-demagnetization dynamics of thin Ni films — •Martin Stiehl, Jonas Hoefer, Sebastian Weber, Sanjay Ashok, Moritz Hofherr, Ute Bierbrauer, Benjamin Stadtmüller, Bärbel Rethfeld, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Kaiserslautern, Germany

After the first observation of the ultrafast demagnetization process, a huge experimental and theoretical effort was devoted to reveal the microscopic mechanism governing the ultrafast optically induced loss of magnetic order in ferromagnetic materials. Almost all experimental fs-demagnetization studies so far employed fs light pulses of 1.55 eV to trigger the magnetization-dynamics. Hence, the role of the photon energy of the exciting light pulse has not been thoroughly investigated so far. Therefore, we have implemented an all-optical time-resolved MOKE setup with variable pump photon energy in the range of 1.55 to 3.10 eV. As prototypical system, we investigated the ultrafast demagnetization dynamics of thin Ni films on insulating and conducting substrates for various excitation photon energies. The characteristic parameters of the demagnetization process, i.e., the demagnetization time and the induced magnetization in the conducting substrate, are compared with simulations applying Boltzmann collision integrals including the density of states of Nickel to describing the non-equilibrium dynamics of the spin-carrying excited electrons.

MA 2.5 Mon 10:30 HSZ 101

Role of spin resolved charge and heat transport in ultrafast demagnetization dynamics — •Sanjay Ashok, Sebastian Weber, Christopher Seibel, Johan Briones, and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS , TU Kaiserslautern, Kaiserslautern, Germany.

Starting from the itinerant picture of metallic magnetism (Stoner-model) and the ultrafast reduction of exchange-splitting [1, 2] the Thermodynamic μT-model [3] describes ultrafast quenching of magnetization by tracing the equilibration of chemical potentials and temperatures of spin-up and spin-down electrons and temperature of lattice separately.

In case of thin metallic ferromagnets, the laser pulse heats the material homogeneously, therefore transport effects can be neglected. However, for thicker films and bulk materials, transport effects become essential. Therefore, one needs to distinguish the role of heat and charge transport (caused by the inhomogenous heating) in demagnetization dynamics of thicker metallic ferromagnets.

We model the ultrafast demagnetization of thick magnetic metal using the Thermodynamic μT-model. In this talk we present results on spatial and temporal evolution of magnetization, distinguishing the role of various transport channels.

[1] S. Essert and H. C. Schneider, Phys. Rev. B 84, 224405 (2011).
[2] B. Y. Mueller et al., Phys. Rev. Lett.111, 167204 (2013).
[3] B. Y. Mueller and B. Rethfeld, Phys. Rev.B 90, 144420 (2014).

MA 2.6 Mon 10:45 HSZ 101

Influence of a non-magnetic substrate on optically induced transport in a ferromagnetic alloy — •Simon Häuser[1], Moritz Hofherr[1], Martin Stiehl[1], Jonas Hoefer[1], Martin Anstett[1], Gregor Zinke[1], Laura Scheuer[1], Sebastian Thomas Weber[1], Christopher Seibel[1], Daniel Steil[2], Stefan Mathias[2], Bärbel Rethfeld[1], Philipp Pirro[1], Burkard Hillebrands[1], Benjamin Stadtmüller[1] und Martin Aeschlimann[1] — [1]TU Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany — [2]Georg-August-Universität Göttingen, I. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Optical manipulation of magnetic materials on extremely short, sub-100fs timescales can be achieved either by generation and injection of optically induced (ballistic) spin currents or by direct excitation of the spin system, i.e., by the optically induced spin transfer (OISTR) effect. In this work, we aim to reveal the mutual interplay of these spin transfer effects on ultrafast timescales. Therefore, we investigate the ultrafast demagnetization of a thin Fe20Ni80 alloy on a non-magnetic Au substrate as well as the influence of the spin current into the Au substrate. As an element-resolved probe of the spin dynamics, we employ time resolved Kerr spectroscopy at the M-edge in transversal geometry to disentangle the spectroscopic signatures of the OISTR and ballistic spin transport in this material. Our results will be compared to the magnetization dynamics of a Fe20Ni80 film on an insulating substrate.

15 min. break.

MA 2.7 Mon 11:15 HSZ 101

Anomalous ultrafast optical demagnetization in stripe domain films — •Derang Cao[1,2], Roman Adam[1], Fangzhou Wang[1], Sarah Heidtfeld[1], Christian Greb[1], and Claus M. Schneider[1] — [1]Peter Grünberg Institute, Research Centre Jülich, 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China

Recently, laser pump/resonant-X-ray-scattering-probe experiments showed that the regular stripe domain (SD) pattern in CoPd films changes into a labyrinth domain structure after laser pulse excitation [Phys Rev B. 2015;91(5):054416]. This observation leads to an assumption that the films with different SD may exhibit different ultrafast demagnetization response on ultrafast time scales. If this is a case, clarifying the interaction mechanism between the domains and sea of spins on ultrafast time scales may contribute strongly to the understanding the mechanisms of ultrafast spin dynamics.

In this work, a train of 80-fs optical pulses has been used to induce a partial quenching of the magnetization in a wedge Ni80Fe20 film (thickness varying from 25 to 370nm). The magnetization distribution along the wedge direction shows thickness-dependent in-plane or out-of-plane orientation. The magnetization dynamics measurements show substantially faster magnetization recovery of films with SD compared to the homogeneously in-plane magnetized films. We expect that an additional anisotropy introduced in the local region by the SD allows for faster magnetization recovery.

MA 2.8 Mon 11:30 HSZ 101

Optically-induced spin dynamics in NiFe/Pd multilayers investigated using soft X-rays and THz radiation — •Sarah Heidtfeld[1], Roman Adam[1], Daniel E. Bürgler[1], Fangzhou Wang[1], Christian Greb[1], Derang Cao[1,2], and Claus M. Schneider[1] — [1]Research Centre Jülich, Peter Grünberg Institute, 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China

In our earlier work we demonstrated that Pd in NiPd alloys exhibits a non-zero magnetic moment and shows transient demagnetization when excited with a train of femtosecond laser pulses [1]. Most importantly, we showed that ultrafast demagnetization depends on the Pd concentration and that the effect can be attributed to an increased spin-flip probability, which is proportional to the amount of Pd in the alloys. In our present work, we elucidate the role of super-diffusive spin currents in the process of optically inducing transient magnetization in metals close to the Stoner transition. We compare demagnetization times in NiPd alloys and NiFe/Pd multilayers by applying the time-resolved magneto-optical Kerr-effect (MOKE) using either visible or extreme ultraviolet (XUV) light. In addition, we analyze the generated spin currents flowing from the NiFe into the Pd layer by investigating THz radiation emitted from these ferromagnet (FM)/heavy metal (HM) double-layers due to the inverse spin Hall effect [2]. Our data provide further insight into the spin and charge dynamics in FM/HM multilayers. [1] S. Gang et al., Phys. Rev. B 97, 064412 (2018) [2] R. Adam et al., Appl. Phys. Lett. 114, 212405 (2019)

MA 2.9 Mon 11:45 HSZ 101

Spin Relaxation and Domain Wall Dynamics in Optically Excited Ferromagnetic [Co/Pt]3 Multilayers — •Fangzhou Wang[1], Roman Adam[1], Daniel E. Bürgler[1], Derang Cao[1,2], Umut Parlak[1], Sarah Heidtfeld[1], Christian Greb[1], and Claus M. Schneider[1] — [1]Peter Grünberg Institute, Research Centre Jülich, 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China

Earlier, we demonstrated [1] that the area of the laser-modified magnetization decreases with the reduced repetition rate at room temperature, but remains constant at low temperature. The strong temperature dependence indicates that thermally activated domain wall motion (TA-DWM) plays an important role in the spin dynamics triggered by a fs laser pulse. In this work, we investigate in detail the relaxation processes following the femtosecond excitation in out-of-plane (OOP) magnetized [Co(0.4 nm)/Pt(0.7 nm)]3 multilayers by performing time-resolved MOKE measurements at varying magnetic field and laser power. We determine the time scales relevant for intrinsic and extrinsic magnetization relaxation processes. Based on the recorded magnetization dynamics transients and assuming TA-DWM as an additional relaxation mechanism, we estimate a time-dependent domain wall velocity for magnetization relaxation. Our analysis contributes to an understanding of spin relaxation processes in OOP magnetized multilayers on the picosecond time scale. [1]U. Parlak, R. Adam, D. E. Bürgler, S. Gang, and C. M. Schneider, Physical Review B 98, 214443 (2018).

MA 2.10 Mon 12:00 HSZ 101

Laser excitation induced ultrafast demagnetization and perpendicular magnetic anisotropy reduction in a $Co_{88}Tb_{12}$ thin film — •Marcel Hennes[1], Alaa el dine Merhe[1], Valentin Chardonnet[1], Xuan Liu[1], Clemens von Korff Schmising[3], Benoît Mahieu[4], Michel Hehn[5], Gregory Malinowski[5], Flavio Capotondi[6], Emanuele Pedersoli[6], Emmanuelle Jal[1], Jan Lüning[1,2], and Boris Vodungbo[1] — [1]Sorbonne Université - LCPMR, CNRS, Paris, France — [2]Synchrotron SOLEIL, Gif-sur-Yvette, France — [3]Max-Born-Institut, Berlin, Germany — [4]Laboratoire d'Optique Appliquée (LOA), Palaiseau, France — [5]Institut Jean Lamour (IJL), Nancy, France — [6]FERMI, Elettra-Sincrotrone, Trieste, Italy

We use time resolved resonant magnetic x-ray scattering experiments, performed at the Co M- and Tb O-edge, to study laser-induced demagnetization effects in a ferrimagnetic $Co_{88}Tb_{12}$ alloy with magnetic stripe domain structure. We evidence an ultrafast decrease of magnetization on sub-ps timescales in the Co as well as in the Tb sublattice and we provide a quantitative description of the demagnetization behavior. Combining the femtosecond temporal with nanometer spatial resolution of our pump-probe experiments, we show that on ultrashort timescales (<1 ps), no detectable change in domain size and domain wall size occurs. However, we evidence a broadening of the domain walls, setting in after approximately 4 ps, which we attribute to a decrease of the uniaxial anisotropy due to energy transfer to the lattice.

MA 2.11 Mon 12:15 HSZ 101

Ultrafast demagnetisation and recovery of chiral magnetic domain walls probed by dichroic X-ray magnetic scattering — •Nico Kerber[1], Dmitriy Ksenzov[2], Frank Freimuth[3], Flavio Capotondi[4], Boris Seng[1], Joel Cramer[1], Hartmut Zabel[1,5], Yuriy Mokrousov[1,3], Mathias Kläui[1], and Christian Gutt[2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099, Mainz, Germany — [2]Department Physik, Universität Siegen, Walter-Flex-Strasse 3, 57072, Siegen, Germany — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [4]FERMI, Elettra-Sincrotrone Trieste, 34149, Basovizza, Trieste, Italy. — [5]Department of Physics, Ruhr-University Bochum, 44780 Bochum, Germany

We employ pulses from a XUV free-electron laser and investigate time-resolved the evolution of the chirality of domain walls in magnetic thin film samples by an IR pump - X-ray magnetic scattering (XRMS) probe experiment. Using samples with interfacial DMI and perpendicular magnetic anisotropy exhibiting labyrinth-like domain patterns we measure in the same experiment both the dichroic signal related to the chirality of the domain walls and the sum signal related to the average domain magnetisation. We observe an ultrafast decrease of both signals in the subpicosecond regime with similar time constants. However, we find a significantly faster recovery of the chiral signal on the sub-ns timescale.

MA 3: Complex Oxides: Bulk Properties (jointly with DS, HL, KFM, MA, O) (joint session TT/MA/HL)

Time: Monday 9:30–13:00 Location: HSZ 201

MA 3.1 Mon 9:30 HSZ 201

Single-crystal growth and magnetic phase diagram of $TbFeO_3$ — •Alexander Engelhardt[1], Georg Benka[1], Christian Oberleitner[1], Andreas Bauer[1], Andreas Erb[2], and Christian Pfleiderer[1] — [1]Physik Department E51, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Walther-Meißner-Str. 8, 85748 Garching, Germany

Single crystals of the multiferroic rare earth orthoferrite $TbFeO_3$ were synthesized by means of optical float-zoning. The magnetization, the longitudinal and the transverse ac susceptibility, as well as the specific heat were measured at low temperatures under large applied magnetic fields to determine the complex, anisotropic magnetic phase diagram of $TbFeO_3$ along the three major crystallographic axes. Taken together, our data are consistent with previous studies reported in the literature. As a new result we identify clear evidence in the bulk properties of the formation of a soliton lattice in a small temperature range, so far observed by means of neutron scattering only.

MA 3.2 Mon 9:45 HSZ 201

Melting of excitonic dispersion in $LaCoO_3$: theory and experiment — Atsushi Hariki[1], Ru-Pan Wang[2], Andrii Sotnikov[1,3], Keisuke Tomiyasu[4], Davide Betto[5], Nicholas B. Brookes[5], Yohei Uemura[2], Mahnaz Ghiasi[2], Frank M. F. de Groot[2], and •Jan Kuneš[1,6] — [1]Institute of Solid State Physics, TU Wien — [2]Debye Institute for Nanomaterials Science, Utrecht University — [3]Akhiezer Institute for Theoretical Physic, Kharkiv — [4]Department of Physics, Tohoku University — [5]European Synchrotron Radiation Facility, Grenoble — [6]Institute of Physics, Czech Academy of Sciences

We present Co L_3-edge resonant inelastic x-ray scattering (RIXS) on bulk $LaCoO_3$ across the thermally-induced spin-state crossover around 100 K. Owing to a high energy resolution of 20 meV, we observe unambiguously the dispersion of the intermediate-spin (IS) excitations in the low temperature regime. Approaching the intermediate temperature regime, the IS excitations are damped and the bandwidth reduced. The observed behavior can be well described by a model of mobile IS excitons with strong attractive interaction, which we solve using dynamical mean-field theory for hard-core bosons. Our results provide a detailed mechanism of how HS and IS excitations interact to establish the physical properties of cobaltite perovskites.

MA 3.3 Mon 10:00 HSZ 201

Spin Selective Quasi-Particle Interference in $PdCoO_2$ — •Dibyashree Chakraborti[1,2], Chi Ming Yim[1], Luke Rhodes[1], Seunghyun Khim[2], Andrew Mackenzie[1,2], and Peter Wahl[1] — [1]School of Physics and Astronomy, St. Andrews, Scotland, United Kingdom, KY169SS — [2]Max Planck Institute of Chemical Physics of Solids, Noethnitzer Strasse, Dresden -01187

The metallic delafossite $PdCoO_2$, which is among the most conductive oxides currently known (at 295 K) [1], has risen to prominence due to interesting physical effects, such as unusually long mean free paths, leading to hydrodynamic effects being observed in electron flow [2]. Further, recent Angle Resolved Photoemission Spectroscopy (ARPES) studies have reported exciting surface-physics on the CoO_2-terminated surface. The CoO_2 surface shows evidence of large Rashba spin-splitting, arising from the interplay of energy scales due to strong spin orbit coupling and inversion symmetry breaking at the surface. [3]. In this study, we have identified and investigated the CoO_2 termination of $PdCoO_2$ with low temperature Scanning Tunneling Microscopy (STM). We present and discuss the quasi-particle interference imaging of the Rashba spin-split surface state, and the implications for possible spintronics applications.

[1] C.W. Hicks et al., Phys. Rev. Lett. 109, 116401 (2012)
[2] P.J.W. Moll et al., Science 351, 1061 (2016)
[3] V. Sunko et al., Nature 549, 492 (2017)

MA 3.4 Mon 10:15 HSZ 201

Interplay of Electronic and Spin Degrees in Ferromagnetic $SrRuO_3$: Anomalous Softening of the Magnon Gap and Stiffness — •Kevin Jenni[1], Stefan Kunkemöller[1], Daniel Brüning[1], Thomas Lorenz[1], Yvan Sidis[2], Astrid Schneidewind[3], Augustinus Agung Nugroho[4], Achim Rosch[5], Daniil Iljitsch Khomskii[1], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln, Deutschland — [2]Laboratoire Leon Brillouin, Grenoble, Frankreich — [3]JCNS, Forschungszentrum Jülich, Garching, Deutschland — [4]Institut Teknologi Bandung, Indonesien — [5]Institut für Theoretische Physik, Universität zu Köln, Deutschland

We succeeded to grow large single crystals of $SrRuO_3$ using the floating-zone technique [1,2]. The first inelastic neutron scattering study of the spin dynamics on single crystals yields the expected quadratic spin wave dispersion of a ferromagnet. However the magnon gap and stiffness considerably deviate from an earlier inelastic neutron scattering study on powders [3]. In addition we find a non-monotonous temperature dependence of the anisotropy gap and a softening of the magnon stiffness upon cooling. We discuss how Weyl points caused by SOC in $SrRuO_3$ couple electronic and spin degrees of freedom and how this interplay leads to the characteristic behavior in the spin dynamics [4].

[1] S. Kunkemöller et al., Chrys. Res Tec. 51, 299 (2016)
[2] S. Kunkemöller et al., PRB 96, 220406(R) (2017)
[3] S. Itoh et al., Nat. Commun. 7, 11788 (2016)
[4] K. Jenni et al., Phys. Rev. Lett. 123, 017202 (2019)

MA 3.5 Mon 10:30 HSZ 201

Ca_2RuO_4: DFT + DMFT study of the magnetic order and dynamical susceptibility — •Dominique Geffroy[1,2], Kyo-Hoon Ahn[1], Hoshin Gong[4], and Jan Kuneš[1,3] — [1]TU Wien, Vienna, Austria — [2]Masaryk University, Brno, Czech Republic — [3]Czech Academy of Science, Prague, Czech Republic — [4]Max Planck POSTECH/Korea Research Initiative, Pohang, Korea

Relativistic Mott insulators are complex compounds in which spin and orbital degrees of freedom become entangled due to a large spin-orbit coupling. Previous studies, both experimental and theoretical[1, 2], have shown that they are good candidates for novel forms of order, including excitonic magnetism[3]. We report results on the theoretical study of the prototypical relativistic Mott insulator Ca_2RuO_4. We use a realistic ab initio DFT + DMFT approach including SU(2) Coulomb interaction and spin-orbit coupling. The emergence of antiferromagnetic order at low temperature is correctly described. We present and discuss the spectra of the the collective modes in the ordered phase within the DMFT approximation.

[1] Jain et al., Nat. Physics 13, 633 (2017)
[2] G. Zhang and E. Pavarini, Phys. Rev. B 95, 075145 (2017)
[3] A. Akbari and G. Khaliullin, Phys. Rev. B 90, 035137 (2014)

MA 3.6 Mon 10:45 HSZ 201

LDA+DMFT Approach to Resonant Inelastic X-Ray Scattering in Rare-Earth Nickelates — •Mathias Winder[1], Atsushi Hariki[1], and Jan Kuneš[1,2] — [1]Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria — [2]Institute of Physics, Czech Academy of Sciences, Na Slovance 2, 182 21 Praha 8, Czechia

We present a computational study of L-edge resonant inelastic x-ray scattering (RIXS) across the metal-insulator transition (MIT) of $LuNiO_3$. We apply exact diagonalization to a material specific Anderson impurity model with a by DMFT obtained hybridization function. In contrast to other available methods, this approach enables us to describe simultaneously localized (d-d) and delocalized (unbound electron-hole pair) excitations in the RIXS spectra. We reproduce the experimentally observed behaviour of fluorescence-like and Raman-like features across the MIT and provide its material specific interpretation.

MA 3.7 Mon 11:00 HSZ 201

Interplay of electronic correlations, charge disproportionation and lattice in $RNiO_3$ nickelates with R = Lu, Y, and Bi — •Ivan Leonov — M. N. Mikheev Inst. of Metal Physics, Yekaterinburg, Russia — NUST 'MISiS', Moscow, Russia

In recent years, increasing attention has been drawn to the understanding of the rare-earth-element nickelate perovskites $RNiO_3$, which exhibit a sharp metal-insulator transition (MIT). The MIT is accompanied by a structural phase transformation, complicated by the appearance of unusual charge order and non-collinear magnetic phases in the Mott insulating regime. Here, I will focus on this particular problem and will discuss an application of the DFT+DMFT method to explore the electronic structure, magnetic and lattice properties of a series of $RNiO_3$ nickelates with R = Lu, Y, and Bi. I will discuss our results for the pressure-induced Mott MIT in $RNiO_3$, which is found to be accompanied by a structural transformation. While the rare-earth and Bi $RNiO_3$ are closely related in their electronic state and crystal structure, these materials exhibit sufficiently different electronic properties. Our results for $BiNiO_3$ suggest the important role of the Bi 4s charge ordering (charge difference of ∼0.52 electrons), with a charge transfer between the Bi 4s and O 2p states and a stable Ni^{2+} configuration, for understanding of the MIT in $BiNiO_3$ [1]. We find that electronic correlations are important to explain the electronic structure, magnetic state, and lattice stability of $RNiO_3$ (R = Lu, Y, and Bi).

[1] I. Leonov et al., Phys. Rev. B **100**, 161112(R) (2019).

15 min. break.

MA 3.8 Mon 11:30 HSZ 201

Origin of orbital ordering in $LaTiO_3$ and $YTiO_3$ — •Xuejing Zhang and Eva Pavarini — Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

The origin of orbital ordering (OO) in correlated oxides is strongly debated. Two main mechanisms have been proposed as possible explanation for OO phenomena. The first is the classical Jahn-Teller effect and the second is the electronic super-exchange, introduced by Kugel-Khomskii. In the case of the paradigmatic e_g systems $KCuF_3$ and $LaMnO_3$ it has been shown that the electronic Kugel-Khomskii mechanism is not sufficient to drive the OO transition alone, at the temperatures at which orbitally order is typically observed by the co-operative Jahn-Teller distortion.[1,2] In the case of t_{2g} compounds, however, the problem remains open. In these systems both the electron-lattice coupling and the hopping integrals are typically smaller than those for e_g compounds; on the other hand, orbital degeneracy is larger, which enhances the effects of super-exchange. Here we investigate representative t_{2g}^1 systems in which OO is observed, the Mott insulators $LaTiO_3$ and $YTiO_3$. We show that the Kugel-Khomskii transition temperature is about 390 K, comparable to the one of $KCuF_3$. This shows that static distortions are needed to explain the presence of OO at high temperature.

[1] E. Pavarini, E. Koch and A. I. Lichtenstein, Phys. Rev. Lett. 101, 266405 (2008).
[2] E. Pavarini and E. Koch, Phys. Rev. Lett. 104, 086402 (2010).

MA 3.9 Mon 11:45 HSZ 201

Charge transport in oxygen-deficient $EuTiO_3$: The emerging picture of dilute metallicity in quantum-paraelectric perovskite oxides — •Johannes Engelmayer[1], Xiao Lin[1], Christoph Grams[1], Raphael German[1], Tobias Fröhlich[1], Joachim Hemberger[1], Kamran Behnia[2], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Laboratoire Physique et Etude de Matériaux, PSL Research University, 75005 Paris, France

Quantum paraelectric $SrTiO_3$ is a large-gap band insulator that becomes metallic upon electron doping already at extremely small charge-carrier concentrations $\simeq 5 \times 10^{17}\text{cm}^{-3}$. The observed T^2 resistivity in this material challenges conventional theories for electron–electron scattering. We report on a study of charge transport in the related compound $EuTiO_3$ where the carrier density is tuned via reduction. Because of a lower electric permittivity, the metal–insulator transition (MIT) in $EuTiO_{3-\delta}$ occurs at higher carrier densities compared to doped $SrTiO_3$. The critical carrier concentration n_c for the MIT is discussed in the context of the so-called Mott criterion and compared with other doped perovskite compounds with a quantum-paraelectric parent. Similar to doped $SrTiO_3$, $EuTiO_{3-\delta}$ shows a distinct AT^2 resistivity, where the prefactor A scales with n. Using a simple three-band model, the $A(n)$ behavior in doped perovskite titanates can be described over a large range of n.

Funded by DFG via CRC1238 and via ANR-DFG LO 818/6-1 and HE 3219/6-1.

MA 3.10 Mon 12:00 HSZ 201

Magnetic Phase diagram and thermal expansion studies of $NiTiO_3$ — •Kaustav Dey[1], Sven Sauerland[1], Johannes Werner[1], Rabindranath Bag[2], Surjeet Singh[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics , Heidelberg University, Germany — [2]IISER Pune, Maharashtra, India

We report the magnetic phase diagram of $S = 1$ magnetodielectric $NiTiO_3$ single crystals grown by the optical floating zone technique. The high-quality single crystals have been studied by specific heat, by magnetometry up to 60 T, and by thermal expansion and magnetostriction measurements up to 15 T, respectively. The compound evolves long-range antiferromagnetic order at $T_N = 22.5$ K with spins lying in the $ab-$plane. Pronounced anomalies in the thermal expansion coefficients $(\alpha_i,(i = a,b))$ at T_N indicate strong magnetoelastic coupling in $NiTiO_3$. Magnetic length and entropy changes as detected by α and c_p obey Grüneisen scaling which evidences one dominant (spin) degree of freedom driving the transitions. In addition, the magnetic phase diagram features a spin-reoriented phase below $B_c = 1.2$ T which suggests the presence of a small in-plane anisotropy. Notably, spin-reorientation is associated with a first-order-like anomaly in the magnetostriction. The high-field behavior of magnetization is linear and isotropic with saturation at 36 T thereby facilitating constructing the entire magnetic phase diagram.

MA 3.11 Mon 12:15 HSZ 201

Low-Energy Excitations in $NiTiO_3$ and $Ni_{0.25}Mn_{0.75}TiO_3$ Probed by Antiferromagnetic Resonance — •Martin Jonak, Kaustav Dey, Johannes Werner, Changhyun Koo, and Rüdiger Klingeler — Kirchhoff Institute of Physics, Heidelberg University, Heidelberg, Germany

We study magnetic excitations in $NiTiO_3$ and $Ni_{0.25}Mn_{0.75}TiO_3$ by means of X-band and high-frequency electron spin resonance spectroscopy. Our data for $NiTiO_3$ show that in the antiferromagnetically ordered and spin-reoriented phase, i.e. below T_N and in external magnetic fields above the spin-reorientation field $B_C = 1.13(8)$ T, antiferromagnetic resonance (AFMR) modes are well described by a two-sublattice model with an easy ab-plane. Correspondingly, two zero-field excitation gaps are deduced at $\Delta_1 \approx 15$ GHz and $\Delta_2 = 185(2)$ GHz, respectively. At $B < B_C$, an additional magnon mode is observed, which rules out a simple two-sublattice model, thereby contradicting the presently established picture of the low-field ground state. The strongly Mn-doped $Ni_{0.25}Mn_{0.75}TiO_3$ exhibits at least two antiferromagnetically ordered phases. The low-temperature phase shows AFMR modes of a two-sublattice antiferromagnet with anisotropy gaps $\Delta_1 = 29(1)$ GHz and $\Delta_2 = 139(3)$ GHz.

MA 3.12 Mon 12:30 HSZ 201

Electronic transformations in the semi-metallic transitional oxide Mo_8O_{23} — •Venera Nasretdinova[1], Yaroslav Gerasimenko[1,2], Jernej Mravlje[2], Gianmarco Gatti[3], Petra Sutar[2], Damjan Svetin[1,2], Anton Meden[4], Viktor Kabanov[2], Alexander Kuntsevich[5,6], Marco Grioni[3], and Dragan Mihailovic[1,2] — [1]CENN Nanocenter, Ljubljana, Slovenia — [2]JSI, Ljubljana, Slovenia — [3]Institute of Physics, EPFL, Lausanne, Switzerland — [4]University of Ljubljana, Slovenia — [5]LPI of RAS, Moscow, Russia — [6]HSE, Moscow, Russia

Mo_8O_{23} is a low-dimensional stoichiometric transitional metal oxide from MoO_{3-x} family. Its room-temperature phase associated with charge density wave (CDW) is accompanied by non-monotonic resistivity at low temperatures well below structural transitions. Using tunneling and angle-resolved spectroscopy, transport measurements and density functional calculations we reveal electronic transformations leading to a multi-band correlated ground state [1, 2]. We observe the metal-to-insulator transition at 343 K in resistivity, consistent with CDW onset. At low temperatures, the picture with the only CDW order parameter is broken by the onset of the correlated ground state visible both in transport and spectroscopic probes. Spatially-resolved tunneling spectroscopy studies reveal the emergent electronic texture. We discuss the possible origins of the electronic order that emerge in the absence of any structural or magnetic transitions.

[1] V. Nasretdinova et al., Phys.Rev. B 99, 085101 (2019)
[2] V. Nasretdinova et al., Sci. Rep. 9, 15959 (2019)

MA 3.13 Mon 12:45 HSZ 201

Cr and Ce magnetic ordering in $CeCrO_3$:revisited — •Neetika Sharma[1], Reinhard K. Kremer[1], Clemens Ritter[2], and Fereidoon S. Razavi[3] — [1]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]Institute Laue Langevin, Grenoble 38000, France — [3]Department of Physics, Brock University, St. Catharines, ON, L2S 3A1, Canada

We have investigated the magnetic structure of $CeCrO_3$ using neutron powder diffraction (NPD). $CeCrO_3$ crystallizes with the $GdFeO_3$ structure-type (Pbnm). Earlier neutron diffraction measurements on

$CeCrO_3$ have proposed a G-type afm structure for the Cr and a C-type for the Ce sublattice. The analysis of the magnetic structure for the Ce sublattice had been based on one magnetic peak (102) at d $\sim$ 3.152 Å. However, the proposed C-type coupling for Ce will generate primarily two magnetic Bragg peaks (100) at d $\sim$ 5.47 Å and (102) at d $\sim$ 3.152 Å. We have collected NPD patterns on a sample of $CeCrO_3$ using ILL's D20 high-intensity medium resolution diffractometer and did observe the previously reported magnetic Bragg peak at d $\sim$ 3.152 Å, however significantly less intense than reported before. Simulations indicate that only the presence of magnetic coupling of C-type on the Cr- and the Ce- sublattices can lead to a situation where the magnetic peak (102) at d $\sim$ 3.152 Å is a lot stronger than the (100) Bragg peak at d $\sim$ 5.47Å. Following this proposal we have analyzed our neutron diffraction data very carefully at low temperature (1.5K), and conclude a CyGz type magnetic ordering for the Cr sub-lattice with a very small Cy-component and Cy type coupling for Ce - sublattice.

MA 4: Frustrated Magnets - General 1 (joint session TT/MA)

Time: Monday 9:30–13:00 Location: HSZ 304

MA 4.1 Mon 9:30 HSZ 304

Pressure tuning of the ground state of a frustrated Kondo lattice investigated by Muon Spin Relaxation / Rotation spectroscopy — •Mayukh Majumder[1], Ritu Gupta[2], Philipp Gegenwart[1], Oliver Stockert[3], and Veronika Fritsch[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [2]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [3]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Formation of novel quantum states driven by magnetic frustration are of strong current interest. For metallic Kondo lattices tuned to a quantum critical point (QCP), strong frustration is predicted to cause a severe breakdown of Fermi liquid behavior and a possible metallic spin liquid state. CePdAl is a prototype frustrated Kondo lattice with incommensurate long-range magnetic order (LRO) at about 2.7 K involving only 2/3-rd of the 4f moments. The LRO can be suppressed by hydrostatic pressure exceeding 1 GPa [1] and an extended non-Fermi liquid ground state has been observed up to a pressure of about 1.7 GPa [2]. We have employed Muon Spin Relaxation / Rotation (μSR) at milli-Kelvin temperatures and pressures up to 1.62 GPa as a local technique to determine the nature of the magnetic moments across the quantum critical point in CePdAl.

[1] H. Kitazawa et al. Phys. B, 28, 199 (1994)
[2] Zhao et al. Nature Phys. 10.1038/s41567-019-0666-6 (2019)

MA 4.2 Mon 9:45 HSZ 304

Microscopic meaning of the Goodenough-Kanamori-Anderson (GKA) rule in frustrated cuprates — •Stefan-Ludwig Drechsler[1], Liviu Hozoi[1], Ravi Yadav[1], Satoshi Nishimoto[1,2], Rolf Schumann[2], Jan M. Tomczak[3], Dijana Miloslavlevic[4], and Helge Rosner[4] — [1]IFW-Dresden, D-01171 Dresden Germany — [2]TU Dresden, Germany — [3]Vienna University of Technology, Vienna, Austria — [4]MPI-cPfS, Dresden, Germany

Within the multiband (pd) Hubbard model we consider the influence of the ferromagnetic (fm) intersite exchange K_{pd} and that of the intra-site Hund's rule exchange J_H on bridging O in between two Cu-sites on the NN exchange J_1 within a spin-model for cuprates with edge-sharing elements. Based on quantum chemistry (QC), DFT, GW, and exact calculations for small clusters and extended systems we determine the main interactions and transfer integrals for several representative cuprates with edge-sharing elements. In most such compounds with Cu-O-Cu bond angles near 90^o the relatively large $-J_1 > 230$ K is dominated by a *nonuniversal* $K_{pd} > 100$ meV, i.e. significantly larger than 50 meV adopted previously /1/. In contrast to common belief, $J_H < 0.8$ eV is moderate and somewhat screened. It plays only a *minor* role in the GKA. Moderate J_H-values are in accord with results for superoxides /2/. Enlarged K_{pd} $\sim$200 meV agree with QC for corner-sharing cuprates /3/ and empirically with $CuGeO_3$ ($\sim$ 100 meV) /2/.

[1] Y. Mizuno *et al.*, Phys. Rev. B **57**, 5326 (1998).
[12] M. Matsuda *et al.*, ibid. **100** 104415 (2019) and references therein.
[3] M.S. Hybertsen *et al.*, ibid. **45**, 10032 (1992).

MA 4.3 Mon 10:00 HSZ 304

Magnetic interactions in the new double perovskite Nd_2ZnIrO_6, probed by Resonant Elastic X-ray Scattering (REXS) — •Florian Heinsch[1,2], Morgan Allison[2], Sonia Francoual[3], Jochen Geck[2], Florian Rasch[4], Tobias Ritschel[2], Quirin Stahl[2], Raman Thiyagarajan[1,2], Michael Vogl[4], Eugen Weschke[5], and Sabine Wurmehl[4] — [1]HZDR, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]DESY, Hamburg, Germany — [4]IFW, Dresden, Germany — [5]HZB, Berlin, Germany

The unique interplay of spin-orbit coupling, crystal field splitting and Coulomb repulsion have made double perovskites of the general formula $A_2BB'O_6$ with a 5d transition metal sitting on the B'-site a subject of intense research. Recently a new series Ln_2ZnIrO_6 with Ln = Nd, Sm, Eu and Gd and Ir as 5d-elment could be synthesized [1]. In this series, Nd_2ZnIrO_6 stands out because of its particularly intriguing magnetic properties.

Here we present results of REXS experiments on a Nd_2ZnIrO_6 single crystal, conducted at P09 at PETRA III and UE46 PGM-1 at BESSY. The combined capabilities of both facilities provided us with temperature (down to ~5K) and magnetic magnetic field (up to ~13T) dependent data that elucidate the particularly strong correlation between the two magnetic sublattices of the Nd^{3+} and Ir^{4+} ions. An outlook will be given on how to put the found field dependent anisotropy in a comprehensive picture of the magnetic ground state of Nd_2ZnIrO_6 and how that relates to compounds with different Ln.

[1] M. Vogl et al., arXiv:1910.13552

MA 4.4 Mon 10:15 HSZ 304

Crystal growth and characterization of $ZrFe_4Si_2$ — •Katharina M. Zoch, Isabel Reiser, Alexander Bodach, Kristin Kliemt, and Cornelius Krellner — Physikalisches Institut, Goethe Universitaet Frankfurt, 60438 Frankfurt, Germany

The crystal structure of $ZrFe_4Si_2$ consists of edge-linked Fe-tetrahedra along the crystallographic *c*-direction. This type of arrangement is prone to show frustration and low dimensional fluctuations. First results indicate that $ZrFe_4Si_2$ displays some sort of weak magnetic order at unusual low temperatures for a Fe-based compound, as well as deviant behavior in specific heat and resistivity measurements [1]. To further investigate these features, we are in need of good quality single crystals. The crystal growth is a challenging subject since the compound is strongly peritectic melting and its melted elements are reactive with common crucible materials under crystal growth conditions. We show first results of the crystal growth from a levitating melt using the Czochralski method. Furthermore, we present the characterization of the obtained samples especially near the suspected magnetic order.

[1] K. Weber: Intermetallic 3d systems close to a magnetic instability: new unusual cases, Dissertation TU Dresden (2017)

MA 4.5 Mon 10:30 HSZ 304

Orientation dependence of the magnetic phase diagram of $Gd_2Ga_5O_{12}$ — •Markus Kleinhans, Christopher Duvinage, and Christian Pfleiderer — Physik-Department, Technische Universität München, D-85748 Garching, Germany

The magnetic properties of $Gd_2Ga_5O_{12}$ (GGG) originate in large, classical spins ($J = S = 7/2$) that interact antiferromagnetically on two interpenetrating hyperkagome lattices. It has long been recognized that this implies, on a classical level, a high degree of frustration with some kind of classical spin liquid at low temperatures. Yet, dipolar interactions are large and may normally be expected to relieve the effects of geometric frustration. Therefore, it has been considered surprising that GGG at zero magnetic field exhibits spin-freezing without evidence for long-range order, where the recent observation of antiferromagnetic correlations on ten-spin rings, suggests a nematic order parameter, or director. We report vibrating coil magnetometry of the orientation dependence of the magnetic phase diagram of GGG down to mK temperatures, where the applied magnetic field stabilizes a complex sequences of cross-overs and phase transitions that reflect the underlying antiferromagnetic interactions.

MA 4.6 Mon 10:45 HSZ 304

Effective chainlike physics in frustrated $S=\frac{1}{2}$ spin-trimer

Heisenberg magnets $Na_2Cu_3Ge_4O_{12}$ and $K_2Cu_3Ge_4O_{12}$ — •Oleg Janson[1] and Satoshi Nishimoto[1,2] — [1]Leibniz Institute für Festkörper- und Werkstoffforschung (IFW Dresden) — [2]Technische Universität Dresden (TU Dresden)

The trimerized $S = \frac{1}{2}$ Heisenberg magnet $Na_2Cu_3Ge_4O_{12}$ exhibits an incommensurate magnetic order below $T_N = 2\,K$ [1], which is nearly two orders of magnitude smaller than the Weiss temperature $\theta_W \simeq 200\,K$. Its potassium sibling $K_2Cu_3Ge_4O_{12}$ features similar structural Cu_3O_8 trimers, but their connectivity is different. Here, despite the sizable antiferromagnetic $\theta_W = 49\,K$, the magnetic susceptibility $\chi(T)$ reveals no sign of long-range magnetic ordering down to 2.5 K [2]. For both materials, $\chi(T)$ data can not be described within the Heisenberg trimer model. To provide a microscopic insight into the spin models of both materials, we perform microscopic modeling by means of DFT band structure calculations. We find, besides the dominant intertrimer exchange J_1, three (two) further antiferromagnetic exchanges that give rise to a quasi-1D frustrated model in $Na_2Cu_3Ge_4O_{12}$ ($K_2Cu_3Ge_4O_{12}$). The ground states of the spin Hamiltonians are studied using exact diagonalization and DMRG. We also compute the central charge c and the static structure factor $S(q)$, and discuss the possibility to describe the physics of these highly frustrated materials within an effective Heisenberg chain model.

[1] Y. Yasui *et al.*, J. Appl. Phys. **115**, 17E125 (2014).
[2] C. Stoll *et al.*, Inorg. Chem. **57**, 14421 (2018).

MA 4.7 Mon 11:00 HSZ 304

Low-temperature thermal conductivity in the frustrated spin chain mineral Linarite — •Matthias Gillig[1], Xiaochen Hong[1], Gaël Bastien[1], Anja U.B. Wolter[1], Bernd Büchner[1,2], and Christian Hess[1,2] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung, Dresden, Germany — [2]Center for Transport and Devices, TU Dresden, Germany

Motivated by recent theoretical results which predict a finite thermal Drude weight in frustrated spin chains, we have studied the thermal conductivity of the mineral Linarite $PbCuSO_4(OH)_2$ at low temperature. This well-studied material forms a monoclinic structure where a sequence of $Cu(OH)_2$ units forms a S=1/2 spin chain. Competing FM nearest-neighbor and AFM next-nearest-neighbor interactions in this low dimensional spin structure create a magnetically frustrated system which orders below $T_N = 2.8$ K in an elliptical spiral ground state. Upon applying magnetic field along the spin chain direction, other magnetically ordered phases can be induced. For fields of 10 T and higher the spin system is fully polarized. Our results reveal that the thermal conductivity κ in zero field is dominated by a phononic contribution. As a function of magnetic field κ shows a peculiar non-monotonic behavior. Whenever the magnetic field value approaches a critical field, κ is highly suppressed. This trend can be explained by strong magnetic fluctuations which are expected near a phase boundary and which reduce thermal conductivity by phonon scattering.

15 min. break.

MA 4.8 Mon 11:30 HSZ 304

Magnetic properties and phase diagram of the triangular-lattice antiferromagnet $KCeS_2$ — •Bastian Rubrecht[1,2], Gael Bastien[1], Anja U.B. Wolter[1], Sven Luther[3], Hannes Kühne[3], Philipp Schlender[4], Ellen Häussler[4], Thomas Doert[4], and Bernd Büchner[1,2] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Germany — [2]Institute for Solid State and Materials Physics, TU Dresden, Germany — [3]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [4]Faculty of Chemistry and Food Chemistry, TU Dresden, Germany

Triangular-lattice(TL) antiferromagnets are well-known canditates for frustrated magnetism. By introducing different magnetic rare-earth ions, one can change the magnetic interactions to reinforce frustration in these systems. This may lead to the realization of a quantum spin liquid state or to various competing ordered phases, e.g. an oblique version of the 120° state or a collinear up-up-down phase. The delafossite $KCeS_2$ is a new contender realizing anisotropic magnetic interactions. From magnetization measurements of $KCeS_2$-crystals, we observe a strong anisotropy between the basal plane and the c axis. This cannot be explained by g-factor values obtained from single site CASSCF calculations and suggests anisotropic magnetic interactions. Furthermore, our He3 specific heat studies at zero field reveal a phase transition at $T_N = 0.38$ K, which follows a non-monotonous shift as function of an applied in-plane field, resulting in three different magnetic phases in fields up to 9 T. We construct the magnetic phase diagram of $KCeS_2$ and discuss the possible nature of the occurring phases.

MA 4.9 Mon 11:45 HSZ 304

Typical Pure Quantum states and the thermodynamics of highly frustrated quantum magnets — •Andreas Honecker[1] and Alexander Wietek[2] — [1]Laboratoire de Physique Théorique et Modélisation, CNRS (UMR 8089), Université de Cergy-Pontoise, France — [2]Center for Computational Quantum Physics, Flatiron Institute, New York, USA

Reliable computation of the low-temperature thermodynamic properties of highly frustrated quantum magnets remains a considerable challenge. Here we explore the power of Thermal Pure Quantum (TPQ) states implemented in the framework of a Lanczos method using examples of frustrated two-dimensional $S = 1/2$ spin models. In particular, we present accurate results for the specific heat and magnetic susceptibility 2D $S = 1/2$ Shastry-Sutherland model with up to 40 sites in the parameter regime relevant to $SrCu_2(BO_3)_2$ [1] that had remained inaccessible over the previous two decades.

[1] A. Wietek, P. Corboz, S. Wessel, B. Normand, F. Mila, and A. Honecker, Phys. Rev. Research **1**, 033038 (2019).

MA 4.10 Mon 12:00 HSZ 304

Strain-induced order in highly frustrated magnets — •Mary Madelynn Nayga and Matthias Vojta — Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

One defining feature of highly frustrated magnets is a massively degenerate manifold of classical ground states. Here we study how inhomogeneous strain can lift this degeneracy and induce magnetic order in frustrated magnets. We provide explicit examples of strain-induced ordered states and characterize their observable properties, both static and dynamic.

MA 4.11 Mon 12:15 HSZ 304

Quantum criticality of an extended XY-chain with long-range interactions in a transverse field — •Patrick Adelhardt and Kai Phillip Schmidt — Friedrich-Alexander Universität, Erlangen, Germany

The critical breakdown of a one-dimensional quantum magnet with long-range interactions is studied by investigating an extended XY-model in a transverse field for the ferro- and antiferromagnetic case. While for the the limiting case of the pure long-range XY-model we can extract the elementary one-particle excitation analytically, for the long-range Ising limit as well as in the intermediate regime we use perturbative continuous unitary transformations on white graphs in combination with classical Monte Carlo simulations [1] for the graph embedding on the chain to extract high-order series expansions. This allows us to determine the quantum-critical regime including critical exponents.

[1] S. Fey, S.C. Kapfer, K.P. Schmidt, Phys. Rev. Lett. 122, 017203 (2019)

MA 4.12 Mon 12:30 HSZ 304

Quantum criticality of the transverse-field Ising model with long-range interactions on triangular-lattice cylinders — •Jan Koziol, Sebastian Fey, Sebastian C. Kapfer, and Kai P. Schmidt — Lehrstuhl für Theoretische Physik I, Staudtstraße 7, Universitaet Erlangen-Nuernberg, D-91058 Erlangen, Germany

To gain a better understanding of the interplay between frustrated long-range interactions and zero-temperature quantum fluctuations, we investigate the ground-state phase diagram of the transverse-field Ising model with algebraically decaying long-range Ising interactions on quasi-one-dimensional infinite-cylinder triangular lattices. Technically, we apply various perturbative approaches including low- and high-field series expansions, as well as quantum Monte-Carlo stochastic series expansion simulations. For the classical long-range Ising model, we investigate cylinders with an arbitrary even circumference. We show the occurrence of gapped stripe-ordered phases emerging out of the infinitely degenerate nearest-neighbor Ising ground-state space on the two-dimensional triangular lattice. For the full long-range transverse-field Ising model, we concentrate on cylinders with circumference four and six. The ground-state phase diagram consists of several quantum phases in both cases including an x-polarized phase, stripe-ordered phases, and clock-ordered phases which emerge from an order-by-disorder scenario already present in the nearest-neighbor model. In addition, the generic presence of a potential intermediate gapless phase with algebraic correlations and associated Kosterlitz-Thouless transitions is discussed for both cylinders.

MA 4.13 Mon 12:45 HSZ 304

Dynamic Structure Factor of Disordered Coupled-Dimer Heisenberg models — •Max Hörmann and Kai Phillip Schmidt — Institut für Theoretische Physik, Universität Erlangen-Nürnberg, Staudtstraße 7, D-91058 Erlangen

We investigate the impact of quenched disorder on the zero-temperature dynamic structure factor of coupled-dimer Heisenberg models on two-dimensional bilayers on the square, triangular and Kagome lattice. Using perturbative continuous unitary transformations, the effects on quasiparticles are investigated [1]. The disorder leads to intriguing quantum structures in dynamical correlation functions well observable in spectroscopic experiments.

[1] M. Hörmann, P. Wunderlich, K. P. Schmidt, Phys. Rev. Lett. 121, 167201 (2018)

MA 5: Cooperative Phenomena and Phase Transitions (joint session MA/TT)

Time: Monday 9:30–13:15 Location: HSZ 401

MA 5.1 Mon 9:30 HSZ 401

Driving the magnetic transition by chemical substitution in $Cs_{1-x}Rb_xFeCl_3$ — •Lena Stoppel[1], Shohei Hayashida[1], Zewu Yan[1], Severian Gvasaliya[1], Andrey Podlesnyak[2], and Andrey Zheludev[1] — [1]Laboratory for Solid State Physics, ETH Zurich, Switzerland — [2]Neutron Scattering Division, Oak Ridge National Laboratory, Oak Ridge, Tennesse

We report the observation of a chemical-substitution driven phase transition from a gapped quantum paramagnetic phase to one with long range order in $Cs_{1-x}Rb_xFeCl_3$. The $x = 0$ compound in this series of triangular-lattice antiferromagnets has a spin-singlet ground state due to strong easy-plane magnetic anisotropy. In contrast, the $x = 1$ material orders magnetically in a 120° structure [1]. Calorimetric and magnetic experiments performed on a series of samples with $0 \leq x \leq 1$ reveal that in the low-temperature limit magnetic order appears at $x \sim 0.35$. Inelastic neutron scattering experiments show that this coincides with the closure of the gap in the spin excitation spectrum. It appears that disorder effects in this material are more pronounced than those in the only other known phase transition of this type, namely in DTNX [2].

[1] S. Hayashida L. Stoppel et al., Phys. Rev. B 99, 224420 (2019).
[2] K. Yu. Povarov et al., Phys. Rev. B 92, 024429 (2015).

MA 5.2 Mon 9:45 HSZ 401

Lattice effects in pyrochlore compounds $A_2B_2O_7$ — •M. Doerr[1], T. Stoeter[1,2], S. Granovsky[1], S. Zherlitsyn[2], and J. Wosnitza[1,2] — [1]Institut für Festkörper- und Materialphysik, TU Dresden — [2]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf

The magnetic character of pyrochlores $A_2B_2O_7$ (A = rare earths, B = transition metals or p-elements, *e.g.* Ti, Zr, Hf, Sn) strongly depends on the lattice. The ionic radii determine their existence and stability. The question of whether the ground state is degenerated or magnetically ordered is decisively determined by the ratio of dipole and exchange interaction. We present investigations of thermal expansion, magnetostriction and relaxation processes at temperatures down to 0.05 K. $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ show a number of anomalies that can be explained with both exchange and crystal-field effects. These anomalies reflect as well the magnetic properties via magnetoelastic coupling. Thus, statements on the monopole dynamics can be derived from relaxation processes. Relaxation times in the order of 10^3 s evidence the formation and annihilation of monopoles in the kagome-ice and saturated phase, in accordance with the known magnetic phase diagram. In contrast, the lattice effects in $Dy_2Sn_2O_7$ and $Ho_2Sn_2O_7$ are rather negligible. At last, measurements on $Pr_2Zr_2O_7$, $Gd_2Zr_2O_7$ and $Nd_2Hf_2O_7$ allow the direct comparison of classical spin-ice compounds to pyrochlores with light rare earths. A representation-theoretic investigation of the symmetry group of the pyrochlore lattice could lead to a better understanding of the magnetoelastic coupling mechanisms.

MA 5.3 Mon 10:00 HSZ 401

Control of structure and physical properties of La0.7Sr0.3MnO3 thin films via oxygen stoichometry — Lei Cao[1], •Oleg Petracic[1], Paul Zakalek[1], Alexander Weber[2], Ulrich Rücker[1], Jürgen Schubert[3], Alexandros Koutsioubas[2], Stefan Mattauch[2], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT Forschungszentrum Jülich GmbH, Jülich — [2]Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ) Forschungszentrum Jülich GmbH, Garching — [3]Peter Grünberg Institute (PGI9-IT) JARA-Fundamentals of Future Information Technology Forschungszentrum Jülich GmbH, Jülich

Epitaxial thin films of La0.7Sr0.3MnO3 were prepared by high oxygen pressure sputter deposition on SrTiO3 substrates at various oxygen partial pressures. In addition, we performed after preparation systematic oxygen desorption and absorption studies by thermal annealing or oxygen plasma processing, respectively. We derive a phase diagram with respect to the crystal structure (Perovskite vs. Brownmillerite), the magnetic behavior (ferromagnetic vs. antiferromagnetic) and the transport properties (metallic vs. insulating) for various annealing conditions.

MA 5.4 Mon 10:15 HSZ 401

Spin-lattice coupling in a Yafet-Kittel ferrimagnetic spinel — •Atsuhiko Miyata[1,2], Hidemaro Suwa[3], Toshihiro Nomura[2], Lilian Prodan[4], Viorel Felea[2,4,5], Yurii Skourski[2], Joachim Deisenhofer[6], Hans-Albrecht Krug von Nidda[6], Oliver Portugall[1], Sergei Zherlitsyn[2], Vladimir Tsurkan[4,6], Joachim Wosnitza[2,5], and Alois Loidl[6] — [1]LNCMI, Toulouse, France — [2]HLD-HZDR, Dresden Germany — [3]University of Tokyo, Tokyo, Japan — [4]Institute of Applied Physics, Chisinau, Moldova — [5]TU Dresden, Dresden, Germany — [6]University of Augsburg, Augsburg, Germany

Since the discovery of ferrimagnetism in 1948, noncollinear ferrimagnets have been well studied in spinels, AB_2X_4. The key essence is the competition of magnetic exchanges within or between the two A and B lattices. Yafet and Kittel (YK) proposed a model for triangular-structure ground states. To realize unconventional ferrimagnetic structures beyond the YK model, one can consider that spontaneous lattice deformation will modulate these main antiferromagnetic exchanges, i.e., through a spin-lattice coupling mechanism. This kind of spin-lattice coupling mechanism, however, has not been taken into account in previous theoretical works on ferrimagnetic spinels.

In this talk, using ultrasound and magnetostriction results up to 60 T, magnetization measurements up to 110 T, and Monte Carlo calculations, we demonstrate that the spin-lattice coupling induces unconventional magnetic structures under magnetic fields in the YK spinel $MnCr_2S_4$.

MA 5.5 Mon 10:30 HSZ 401

Pressure and field tuning in low-dimensional metal-organic magnets — •Matthew Coak[1], Samuel Curley[1], David Graf[2], Jamie Manson[3], and Paul Goddard[1] — [1]University of Warwick, Coventry, United Kingdom — [2]National High Magnetic Field Laboratory, Tallahassee, FL, USA — [3]Eastern Washington University, Cheney, WA, USA

The 1D molecular magnet $Cu(pyz)(gly)ClO_4$ (gly = glycine, pyz = pyrazine) is an $S = 1/2$ dimer material with small enough exchange constants to address with accessible fields. The dimers are coupled antiferromagnetically, possessing a singlet-triplet energy-gap that can be closed upon application of an external magnetic field. When the Zeeman splitting of the degenerate triplet state initially closes the gap, the system passes through a quantum phase transition from a quantum-disordered ground state to a long-range XY-ordered phase. This excited triplet state can be described as a system of bosonic quasi-particles called 'triplons'. Under certain conditions, this triplon excited state maps onto a Bose-Einstein condensate of magnons; $Cu(pyz)(gly)ClO_4$, at ambient pressures, appears to conform to this picture.

We present our latest results in using hydrostatic pressure as a tuning parameter to control the inter- and intra-dimer exchange interactions and observing the effects on the temperature-field phase diagram.

MA 5.6 Mon 10:45 HSZ 401

Spin crossover in mechanically responsive Ni(II)-MOF-74 — •Dijana Žilić[1], Krunoslav Užarević[1], Senada Muratović[1], Bahar Karadeniz[1], Tomislav Stolar[1], Stipe Lukin[1], Ivan Halasz[1], Mirta Herak[2], Gregor Mali[3], Yulia Krupskaya[4], and Vladislav Kataev[4] — [1]R. Bošković Institute, Zagreb, Croatia — [2]Institute of Physics, Zagreb, Croatia — [3]National Institute of Chemistry, Ljubljana, Slovenia — [4]Leibniz IFW, Dresden, Germany

The metal-organic frameworks (MOFs) are the subject of intensive research not only due to potential applications but also due to unresolved magnetic properties. We present here very detailed study of structural and magnetic properties of Ni(II)-MOF-74 compound, investigated by powder X-ray diffraction, infrared and Raman spectroscopy, magnetization measurements, X-band and multifrequency high-field electron spin resonance and solid state nuclear magnetic resonance spectroscopy. Our results show that Ni-MOF-74 can be described as a zig-zag spin chain system with ferromagnetic intrachain and weaker antiferromagnetic (AFM) interchain interaction, with long-range AFM phase transition around 17 K. We also studied how desolvation and amorphization process can influence the chemical and physical properties of Ni-MOF-74. The observed strong differences in magnetic properties of amorphous Ni-MOF-74 were explained by spin crossover from high-spin to low-spin state of Ni(II) ions.

Supported by HRZZ (UIP-2014-09-4744 and IP-2018-01-3168) and DAAD-MZO projects "Magneto-structural correlations in molecular magnetic complexes studied by electron spin resonance spectroscopy".

MA 5.7 Mon 11:00 HSZ 401

Atomistic simulations of spin-state switching in multinuclear spin-crossover molecules — •Robert Meyer, Christian Mücksch, Juliusz A. Wolny, Volker Schünemann, and Herbert M. Urbassek — Physics Department & Research Center OPTIMAS, University Kaiserslautern, Erwin-Schrödinger-Straße, D-67663 Kaiserslautern, Germany

Spin-crossover materials exhibit the unique ability to switch between a low-spin and a high-spin state, indicating their potential as possible organic storage devices. A switch between the low and the high spin state is reflected by a frequency shift in the phonon density of states. This makes the phonon density of states an interesting tool to analyze spin-crossover materials.

We use a molecular dynamics approach to calculate the phonon density of states for both spin states. In particular, we are interested in the spin-switch behaviour of multinuclear SCO-compounds. We report on spin-switch dynamics depending on chain-length and number of switched atoms.

MA 5.8 Mon 11:15 HSZ 401

Noncoplanar magnetic order induced absence of large anomalous Hall effects in Mn_3Sn — •Xiao Wang[1], Fengfeng Zhu[1], Junda Song[1], Yixi Su[1], and Thomas Brückel[2] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Jülich, Germany

Recent experimental realizations of large anomalous Hall effect (AHE) at room temperature[1] in the non-collinear antiferromagnet (AFM) Mn_3Sn have attracted strong interests on this compound due to its potential applications in antiferromagnetic spintronics devices. We have prepared high quality Mn_3Sn single crystals [2] and studied its physical properties and magnetic structure by various methods. Surprisingly, below a magnetic phase transition at 280 K, the AHE vanished completely along with the emergence of two incommensurate phases. Our further polarized neutron scattering studies show the low temperature magnetic structures are noncoplanar order. Based on the polarized analysis results, we propose several possible magnetic structure models below 280 K. Moreover, we will discuss the reason for disappearance of AHE in the low temperature noncoplanar structures with magnetic symmetry analysis[3] and scalar spin chirality theory.

[1] S. Nakatsuji, et al., Nature 527, 212 (2015). [2] N.H. Sung, et al., Appl. Phys. Lett. 112, 132406 (2018). [3] M.-T. Suzuki, et al. Phys. Rev. B 95, 094406 (2017).

MA 5.9 Mon 11:30 HSZ 401

Magnetic structures and interplay between Eu and Mn in Dirac material EuMnBi2 — •Fengfeng Zhu[1], Xiao Wang[1], Junda Song[1], Thomas Müller[1], Yixi Su[1], and Thomas Brückel[2] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Jülich, Germany

We report here a comprehensive determination of the antiferromagnetic (AFM) structures of Eu and Mn magnetic sub-lattices by using both polarized and non-polarized single-crystal neutron diffraction methods. All the magnetic moments are orientated along c axis, the magnetic propagation vector is (0,0,1) for Eu sub-lattice and (0,0,0) for Mn sub-lattice. With proper neutron absorption correction, the ordered moments are refined as about 7.7 μ_B and 4.1 μ_B for the Eu and Mn ions, respectively, at 3K. In addition, a spin-flop phase transition of Eu moments was confirmed at field $B_c \sim$5.3T along c axis which is constant with previous reported work [1] and the evolution of magnetic moment orientations were also determined. In the spin-flop process, we found a clear kink in the field dependence of magnetic diffraction (1,0,1) of Mn, which unambiguously indicates the existence of strong coupling between Eu and Mn moments [2].

[1] H. Masuda et al., Sci. Adv. 2, e1501117 (2016) [2] A. F. May et al., Phys. Rev. B 90, 075109 (2014)

MA 5.10 Mon 11:45 HSZ 401

Ferrimagnetism in $CeSb_2$: Measuring bulk magnetic properties with an STM — •Christopher Trainer[1], Paul Canfield[2], and Peter Wahl[1] — [1]University of St Andrews, School of Physics and Astronomy, St Andrews, Fife, UK — [2]Iowa state University, Department of Physics and Astronomy, Ames, Iowa, US

$CeSb_2$ is one of a family of rare earth magnetic materials that exhibit metamagnetism where the magnetic state can be changed by an applied magnetic field. At low temperature it exhibits a complex phase diagram with multiple magnetically ordered phases for many of which the order parameter is only poorly understood. In this talk I will report Scanning Tunneling Microscopy and magnetization measurements of $CeSb_2$. I introduce a new mode of STM measurements which allows for the characterization of the sample magnetostriction and thus the construction of a bulk phase diagram using an STM. From the magnetostriction measurement, we determine the bulk phase diagram and validate it by comparison with magnetization measurements. Our magnetostriction and magnetisation measurements indicate the low temperature ground state at zero field is ferrimagnetic. Quasiparticle interference mapping showing how the electronic behaviour develops through the phase diagram will also be discussed.

MA 5.11 Mon 12:00 HSZ 401

Spin-reorientation in CuCr2S4 from μSR — •Elaheh Sadrollahi[1,2], Jochen Litterst[2,3], 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

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

MA 5.12 Mon 12:15 HSZ 401

Epsilon iron as a spin-smectic state — Tommaso Gorni[1] and •Michele Casula[2] — [1]Laboratoire de Physique et d'Étude des Matériaux, École Supérieure de Physique et de Chimie Industrielles

de la Ville de Paris, Université Paris Sciences et Lettres, 75005 Paris, France — [2]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, Sorbonne Université, 4 Place Jussieu, 75005 Paris, France

By first-principles and spin-model calculations, we study the high-pressure epsilon phase of iron. We reveal the existence of a modulated spin pattern, lower in energy than the previous results, where spin fluctuations lead to the formation of antiferromagnetic bilayers separated by null spin bilayers. This pattern is analogous to the smectic phase found in liquid crystals. The magnetic bilayers are likely orientationally disordered, owing to the soft interlayer excitations and the near-degeneracy with other smectic phases. This possible lack of long-range correlation agrees with neutron powder diffraction and could be integral to explaining its puzzling superconductivity.

MA 5.13 Mon 12:30 HSZ 401

Frustration induced highly anisotropic magnetic patterns in classical XY model on kagome lattice — •Alexei Andreanov[1] and Mikhail Fistul[1,2] — [1]IBS PCS, Daejeon, Korea — [2]Russian Quantum Center, Moscow, Russia

We predict and observed novel highly anisotropic magnetic patterns obtained in the classical XY model on kagome lattice. The frustration is provided by the presence of both ferromagnetic (FM) and antiferromagnetic interactions between adjacent magnetic moments. At a critical value of frustration $f_{cr} = 3/4$ the system exhibits a transition from the ferromagnetic state to highly-degenerated ground state. In this regime, $f_{cr} < f \leq 1$, the average magnetization $\langle \vec{M} \rangle \simeq N^{-1/4}$ (N is the number of spins). This scaling originates from highly anisotropic character of the groundstates with the FM ordering along the y-direction, and short-range correlations along the x-direction. These features are explained by the presence of the double-degenerate ground state in a single triangle of the kagome lattice supplied witg a large number of constraints. We anticipate the implementation of this model in various systems, e.g. natural magnetic molecular clusters, artificially prepared Josephson junctions networks, trapped-ions and/or photonic crystals.

MA 5.14 Mon 12:45 HSZ 401

Concept of geometrically controlling artificial magnetoelectric materials — •Oleksii M. Volkov[1], Ulrich K. Rössler[2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, Dresden, Germany — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden e. V. (IFW Dresden), Dresden, Germany

Magnetoelectric materials combine coupled magnetic and electrical order parameters, that allowed to control magnetic states via electrical influence and vice versa [1]. This offers exciting prospectives for energy efficient memory, logic and sensor devices. Here, we propose a new approach to electric field controlled nanomagnets [2], where the manipulation of magnetic states is done geometrically via modification of mesoscale Dzyaloshinskii-Moriya interaction and curvature-induced anisotropy [3]. The concept refers to geometrically curved helimagnetic springs embedded in a piezoelectric matrix or sandwitched between two piezoelectric layers. The electric field induces tiny changes of geometrical parameters, that leads to the transition between homogeneous and periodic helimagnetic states. This results in the appearance of strong converse magnetoelectric effect (CME) 15×10^{-3} (A m^{-1})/(V m^{-1}), which is five times higher than CME for best laminated magnetoelectric composites 2.9×10^{-3} (A m^{-1})/(V m^{-1}).

[1] W. Eerenstein et al., Nature **442**, 759 (2006).
[2] O. Volkov et al., J. Phys. D: Appl. Phys. **52**, 345001 (2019).
[3] O. Volkov et al., Scientific Reports **8**, 866 (2018).

MA 5.15 Mon 13:00 HSZ 401

Orthomagnons and Quantum Weak Ferromagnetism in Kagome Antiferromagnets — •Robin R. Neumann[1], Alexander Mook[2], Jürgen Henk[1], and Ingrid Mertig[1,3] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Department of Physics, University of Basel, CH-4056 Basel — [3]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

Magnons are charge-neutral spin carriers that appear as excitations in magnetically ordered systems. The magnetic moment they carry is often thought to be antiparallel to the localized magnetic moments in the ground state, causing magnons in collinear (or coplanar) magnets to carry only those magnetic moment components offered by the texture.

In this talk, we lift the aforementioned limitation by introducing “orthomagnons,” whose magnetic moment has a component orthogonal to the magnetic texture. We demonstrate that the notion of orthomagnons appears naturally in coplanar antiferromagnets on the kagome lattice. As a consequence, both quantum and thermal fluctuations introduce a weak out-of-plane magnetic moment. In the limit of zero temperature, this gives rise to quantum weak ferromagnetism.

MA 6: Micro- and Nanostructured Materials (joint session MA/TT)

Time: Monday 9:30–11:15 Location: HSZ 403

MA 6.1 Mon 9:30 HSZ 403

Magnetization properties of individual 3D Fe-Co Nanostructures — •Mohanad Al Mamoori[1,2], Fabrizio Porrati[1], Michael Huth[1], Christian Schröder[3], and Jens Müller[1] — [1]Institute of Physics, Goethe University Frankfurt, Germany — [2]Institute of Materials Science, Technical University of Darmstadt, Germany — [3]Institute for Applied Materials Research, Bielefeld University of Applied Sciences, Germany

The transition from 2D to 3D nanomagnetism may bring with it the emergence of novel physical effects and enable future magnetic memory and sensing applications. In [1,2], we have employed focused electron beam induced deposition (FEBID) to grow 3D nanomagnets as nanocubes and nano-trees directly onto a micro-Hall sensor acting both as substrate and high-resolution detection device of small magnetic stray fields. We find that the magnetisation reversal propagates by multi-vortex switching scenarios. In this presentation, firstly, we report systematic measurements of magnetic stray fields of newly grown Fe-Co tetrahedral structures as building blocks of diamond lattices as a function of temperature and magnetic field applied at different angles. Secondly, in order to gain further insights in the hysteresis loops, (irreversible) magnetic interaction effects and coercivity distributions, first-order-reversal curves (FORC) of these 3D nanomagnets supported will be shown. Finally, an outlook to the future design of such structures towards the realization of 3D artificial spin ice architectures will be given. [1] L.Keller et al., *Sci. Rep.* **8** , 6160 (2018). [2] M. Al Mamoori et al., *Materials* **11**, 289 (2018).

MA 6.2 Mon 9:45 HSZ 403

Magnetization reversal in round and square nanodots — •Andrea Ehrmann[1] and Tomasz Blachowicz[2] — [1]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, Bielefeld, Germany — [2]Silesian University of Technology, Institute of Physics - Center for Science and Education, Gliwice, Poland

Ferromagnetic nanodots in different shapes can be applied in data storage, spintronics, neuromorphic computing, etc. Especially the possibility to create vortex states is of high technological interest since these states have significantly reduced stray fields and correspondingly less interaction with neighboring nanodots. Whether a vortex state occurs in the absence of an external magnetic field, depends on the dimensions of the nanodots and, in case of not round nanoparticles, on the shape, since the shape anisotropy significantly influences magnetization reversal processes.

Here we give an overview of magnetization reversal processes in square [1] and round nanodots [2], often including a single-vortex state, while in some cases two, three or even more vortex-antivortex pairs can be found. We also show the stability of single vortex ground states, i.e. the states usually suggested for data storage, which depends strongly on the dot geometry.

[1] A. Ehrmann, T. Blachowicz, Hyperfine Interactions 239, 8 (2018)
[2] A. Ehrmann, T. Blachowicz, J. Magn. Magn Mater. 475, 727-733 (2019)

MA 6.3 Mon 10:00 HSZ 403

Experimentally observable curvature-induced effects in

parabolic nanostripes — •Oleksii M. Volkov[1], Attila Kákay[1], Florian Kronast[2], Ingolf Mönch[1], Mohamad-Assaad Mawass[2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum-Dresden-Rossendorf, Dresden, Germany — [2]Helmholtz-Zentrum Berlin für Materialen und Energie, Berlin, Germany

Dzyaloshinskii-Moriya interaction (DMI) is a key aspect in magnetism that can lead to the appearance of chiral effects, such as the topological Hall effect [1], or to the formation of chiral noncollinear magnetic textures, as skyrmions or chiral domain walls [1]. Curvature effects in magnetism offer means to create chiral interactions like DMI based on the geometry of thin films [2]. This extrinsic tailoring of the DMI (strength and spatial orientation) is in stark contrast to conventional approaches, where chiral interactions are tuned relying on extensive material screening. Very recently, we provide the very first experimental confirmation of the existence of curvature-induced DMI in parabola-shaped Permalloy nanostripes [3,4]. The magnitude of the effect can be tuned by the parabola's curvature and width, while its value is comparable with those experimentally reported for asymmetric Co sandwiches.

[1] N. Nagaosa and Y. Tokura, Nat. Nanotechnol. **8**, 899 (2013).
[2] Y. Gaididei et al., PRL **112**, 257203 (2014).
[3] O. Volkov et al., PRL **123**, 077201 (2019).
[4] O. Volkov et al., PSS-RRL **13**, 1800309 (2019).

MA 6.4 Mon 10:15 HSZ 403

Giant Photovoltaic Effect in Magnetic Materials — •Oles Matsyshyn and Inti Sodemann — MPI PKS, Dresden, Germany

We investigate a rectification process present in materials that break both inversion and time reversal symmetries. At second order in electric fields, this effect is inverseley proportional to the relaxation rate, and, therefore, the rectified current would be infinity in a "naive" ideal clean and zero temperature limit. Employing Floquet theory, we show, however, that there is a non-perturbative correction in the electric field strength that regularises this divergence, but, which ultimately leads to a giant photo-current generation. Therefore, this effect offers a promising alternative paradigm for solar cell technologies.

MA 6.5 Mon 10:30 HSZ 403

Microscopic origin of improved magnetic fluid hyperthermia performance of CFO-Pd heterodimers: Element-specific investigations of structural, electronic, and magnetic characteristics — •S. Fatemeh Shams[1], Detlef Schmitz[2], Alevtina Smekhova[2], Eugen Weschke[2], Kai Chen[2], Chen Luo[2], Amir. H. Tavabi[3], Sussane Pettinger[4], Konrad Siemensmeyer[2], Gil Westmeyer[4], Rafal E. Dunin-Borkowski[3], Florin Radu[2], and Carolin Schmitz-Antoniak[1] — [1]Peter-Grünberg-Institut (PGI-6), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Institute of Biological and Medical Imaging (IBMI), Helmholtz Zentrum München, 85764 Neuherberg, Germany

Cobalt ferrite nanoparticles were synthesized and randomly decorated with approximately 2 wt.% of Pd particles. After careful structural and compositional characterization, X-ray absorption spectroscopy was used to investigate their element-specific magnetic properties. A significant increase in the effective spin and orbital magnetic moments of both the Fe and the Co ions was found upon decoration with Pd, leading to an increase in total magnetic moment per formula unit by 60% for the larger nanoparticles and by 200% for the smaller ones at 300 K. XMCD measurements show that the magnetic field dependence of the Co moment is much steeper at lower magnetic fields, leading to an enhanced maximum heating power in hyperthermia experiments.

MA 6.6 Mon 10:45 HSZ 403

Strain induced orientation of hematite nanospindles studied via Mössbauer spectroscopy — •Damian Günzing[1], Julian Seifert[2], Samira Webers[1], Joachim Landers[1], Annette M. Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Department of Chemistry, Institute of Physical Chemistry, University of Cologne

Magnetic nanoparticles embedded in different matrices are a promising hybrid material class with the opportunity of tayloring the magneto-elastic properties. For an efficiently working hybrid material, it is mandatory to understand the particle matrix interaction on the nanoscale. In this work spatial particle ordering of anisotropic hematite nanospindels [1] is induced via applied strain to an elastomer matrix with incorporated particles. To study the ordering process the focus lies on the element specific Mössbauer spectroscopy with and without an applied magnetic field. With this technique we obtain information about the spin orientation and Brownian diffusion simultaneously from the measured spectra. The distributions in spin orientation are further compared to Monte-Carlo simulations calculating the degree of ordering. As a complementary method, small angle x-ray scattering measurements are performed on the sample systems to determine the ordering parameter from the spatial particle distribution. This work is financially supported by the DFG priority program SPP1681 (WE2623/7-3).

[1] J. Landers et al., J. Phys. Chem. C 119, 20642-20648 (2015)

MA 6.7 Mon 11:00 HSZ 403

Cellulose nanocomposite with $SrFe_{12}O_{19}$ nanoparticles as a novel magnetic nanopaper source — •Andrei Chumakov[1], Calvin Brett[1,2], Artem Eliseev[3], Evgeny Anokhin[3], Lev Trusov[3], Lewis Akinsinde[4], Marc Gensch[1,5], Dirk Menzel[6], Matthias Schwartzkopf[1], Micheal Rübhausen[4], and Stephan Roth[1,2] — [1]DESY, Hamburg, Germany — [2]KTH Royal Institute of Technology, Stockholm, Sweden — [3]MSU, Moscow, Russia — [4]CFEL, Universität Hamburg, Hamburg, Germany — [5]TUM, Garching, Germany — [6]TU Braunschweig, Braunschweig, Germany

The combination of biocompatible cellulose nanofibrils (CNF) with magnetic nanoparticles provides a promising magnetic composite material for flexible and electromechanical devices. Superparamagnetic ferrite nanoparticles are used as a magnetic material for such composites. We combined CNF with a novel type of stable magnetic colloids based on disc-like (diameter 40 nm, thickness 5 nm) hard magnetic hexaferrite ($SrFe_{12}O_{19}$) particles, electrostatically stabilized in aqueous solution. Each particle carries a large permanent magnetic moment oriented perpendicularly to the plate surface (Ms = 50 emu/g, Hc = 4500 Oe). As a result of the interaction of positively charged magnetic particles with a negatively charged surface of the CNF (1360 μmol/g), a thin film of the magnetic composite material was fabricated by spray deposition. The structure was studied by imaging, X-ray scattering and the magnetic techniques of such a composite showed a uniform distribution of single hexaferrite nanoparticles in a cellulose matrix.

MA 7: Topological Phenomena (joint session MA/TT)

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

MA 7.1 Mon 9:30 POT 6

Complex magnetism and colossal magnetoresistance in wallpaper fermion candidate Eu5In2Sb6 — •Marein Rahn[1,2], Sonia Francoual[4], Alessandro Bombardi[5], Pascal Manuel[6], Larissa Veiga[7], Morgan Allison[1], Marc Janoschek[3], Jochen Geck[1], Filip Ronning[2], and Priscila Rosa[2] — [1]IFMP, Technische Universität Dresden, 01069 Dresden, Germany — [2]LANL, Los Alamos, NM 87545, USA — [3]PSI, 5232 Villigen, Switzerland — [4]DESY, 22607 Hamburg, Germany — [5]Diamond Light Source, Didcot OX11 0DE, UK — [6]ISIS Neutron an Muon Source, Didcot OX11 0QX, UK — [7]LCN, University College London, London WC1H 0AH, UK

A new type of hourglass topological surface state has been predicted to be protected by non-symmorphic structural symmetries in Ba5In2Sb6. Following this prediction, we synthesized the isostructural Eu5In2Sb6, which promises to combine the potential for novel electronic topology with the 8 muB magnetic moment of Eu2+. Indeed, we find unusual unusual electronic properties, such as 99% negative magnetoresistance and a two-step magnetic ordering process. We present our complementary use of neutron powder diffraction, Eu L3-edge resonant elastic x-ray scattering and muon spin-rotation to reveal the mechanism of this unusual magnetic ground state, which may form a basis for understanding of the relevance of topological surface states in this material.

MA 7.2 Mon 9:45 POT 6

Large magnetic gap at the Dirac point and spin polarization control in $Bi_2Te_3/MnBi_2Te_4$ heterostructures — •Friedrich Freyse[1], Emile Rienks[1], Stefan Wimmer[2], Andreas Ney[2], Hubert Steiner[2], Valentine Volobuev[2], Heiko Groiss[2], Günther Bauer[2], Andrei Varykhalov[1], Oliver Rader[1], Gunther Springholz[2], and Jaime Sánchez-Barriga[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II, Berlin, Germany — [2]Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität, Linz, Austria

Using spin- and angle-resolved photoemission, we investigate the electronic and spin structure of the topological surface state (TSS) of $Bi_2Te_3/MnBi_2Te_4$ heterostructures as a function of temperature. By cooling below the Curie temperature T_C, we observe how a magnetic surface gap opens at the Dirac point of the initially gapless TSS, a requirement which is crucial to enable the quantum anomalous Hall effect. The spectrum of the gapped Dirac point measured in remanence after field cooling (M+) is clearly spin polarized, with spin orientation perpendicular to the surface plane and spin split by a large value of $\Delta = 56 \pm 4$ meV at 6 K. Subsequent measurement at room temperature shows that the spin polarization completely disappears, whereas subsequent cooling in an oppositely oriented field (M-) leads to a reversal of the spin polarization.
[1] J.Sánchez-Barriga *et al.* Nature (2019), in press

MA 7.3 Mon 10:00 POT 6

Magnetic properties of antiferromagnetic topological insulators — •Martin Hoffmann[1], Mikhail M. Otrokov[2,3,4,5], Arthur Ernst[1], and Evgueni V. Chulkov[2,4,5,6] — [1]Institute for Theoretical Physics, Johannes Kepler Universität, Linz, Austria. — [2]Centro de Física de Materiales (CFM-MPC), Centro Mixto CSIC-UPV/EHU, San Sebastián, Spain. — [3]IKERBASQUE, Basque Foundation for Science, Bilbao, Spain. — [4]Donostia International Physics Center (DIPC), San Sebastián, Spain. — [5]Saint Petersburg State University, Saint Petersburg, Russia. — [6]Departamento de Física de Materiales UPV/EHU, San Sebastián, Spain.

The doping of nonmagnetic topological insulators with magnetic transition metal elements exhibits less desired strongly inhomogeneous magnetic and electronic properties, which restricts the observation of important effects to very low temperatures. Well ordered intrinsic magnetic topological insulators can be the solution to those problems as they show higher magnetic phase transition temperatures as theoretically predicted and experimentally confirmed for the antiferromagnetic (AFM) topological insulator $MnBi_2Te_4$. Here, we report about the *ab initio* results and calculated magnetic properties of this prediction. $MnBi_2Te_4$ forms septuple-layer blocks including a Mn layer. A three-dimensional AFM order establishes below the Néel temperature of $T_N = 25.4$ K obtained by Monte Carlo simulations. This AFM order causes the different Mn layer to align their moments antiparallel due to weak out-of-plane magnetic exchange coupling constants, while the intralayer magnetic order is ferromagnetic.

MA 7.4 Mon 10:15 POT 6

A Family of Intrinsic Magnetic Topological Insulators $(MnBi_2Te_4)(Bi_2Te_3)_n$, $n = 0, 1, 2$ — •Anna Isaeva[1,2], Alexander Zeugner[3], Anja U. B. Wolter[1], Bernd Büchner[1], and Hendrik Bentmann[4] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — [2]Faculty of Physics, Technische Universität Dresden, Dresden, Germany — [3]Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Dresden, Germany — [4]Experimental Physics VII, Universität Würzburg, Würzburg, Germany

In a quest to harness quantum effects for technological advances, new realizations of materials for quantum anomalous Hall effect are pursued. A family of van-de-Waals $(MnBi_2Te_4)(Bi_2Te_3)_n$ compounds derive from the 3D topological insulator Bi_2Te_3 and feature an ordered Mn sublattice. They are the first intrinsic magnetic topological insulators [1]. We obtain high-quality crystals for all n. $(MnBi_2Te_4)(Bi_2Te_3)_n$ are thermodynamically stable in narrow temperature ranges near 873 K. We establish ubiquitous off-stoichiometry of the materials, e.g. $Mn_{1-x}Bi_{2+2x/3}Te_4$ ($x = 0.15$). Temperature- and field-dependent magnetization measurements show a 3D antiferromagnetic order ($T_N = 24$ K) in $MnBi_2Te_4$. It originates from an AFM interlayer coupling of Mn(II) layers with ferromagnetic intralayer coupling. This magnetic ground state and a centrosymmetric space group $R\bar{3}m$ entail the $Z_2 = 1$ topological classification and render $MnBi_2Te_4$ the first AFM TI [1]. [1] M. Otrokov et al. Nature (2019), in press, arxiv.org: 1809.07389.

MA 7.5 Mon 10:30 POT 6

Intriguing magnetic ground state of $MnBi_4Te_7$: a Bi_2Te_3 derivative with a periodic Mn sublattice — •Laura T. Corredor-Bohórquez[1], Vilmos Kocsis[1], Anja U. B. Wolter[1], M. Hossein Haghighi[1], Nicolás Pérez[2], Jorge Facio[3], Bernd Büchner[1,4], and Anna Isaeva[1,4] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, 01069 Dresden, Germany — [2]Institute for Metallic Materials, Leibniz IFW Dresden, 01069, Dresden, Germany — [3]Institute for Theoretical Solid State Physics, Leibniz IFW Dresden, 01069, Dresden, Germany — [4]Faculty of Physics, Technische Universität Dresden, Dresden, Germany

Materials with a combination of non–trivial band topology and long-range magnetic order have been long desired, since it is expected the appearance of novel spintronic phenomena. Following theoretical advances material candidates are emerging. $MnBi_2Te_4$ is the first antiferromagnetic topological insulator [1] and the progenitor of a modular (Bi_2Te_3)n$(MnBi_2Te_4)$ series. For n = 1, it is established an antiferromagnetic state below 13 K followed by a state with net magnetization and ferromagnetic–like hysteresis below 5 K. Through static and dynamic magnetic characterization of single crystals, we build up a picture of the intriguing magnetic ground state of this new compound. Our results render $MnBi_4Te_7$ as a band inverted material with an intrinsic net magnetization and a complex magnetic phase diagram providing a versatile platform for the realization of different topological phases. [1] M. Otrokov et al. Nature (2019), in press. Arxiv.org:1809.07389.

MA 7.6 Mon 10:45 POT 6

Dynamic magnetic properties of a magnetic topological insulator material $MnBi_4Te_7$ — •Kavita Mehlawat[1,3], Alexey Alfonsov[1,3], Anna Isaeva[1,2,3], Bernd Buechner[1,2,3], and Vladislav Kataev[1,3] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — [2]Faculty of Physics, Technische Universität Dresden, Dresden, Germany — [3]Würzburg-Dresden Cluster of Excellence ct.qmat

A van der Waals compound $MnBi_4Te_7$ belongs to the family of (Bi_2Te_3)n$(MnBi_2Te_4)$, (n = 0, 1, 2) heterostructures and is a candidate magnetic topological insulator [1]. It is the first magnetic material that features both, the intrinsic net magnetization and a band inversion. Static magnetic susceptibility (χ) and magnetization (M) measurements as a function of the applied field (H) on $MnBi_4Te_7$ single-crystals show an antiferromagnetic state at $T_N = 13$ K and a ferromagnetic-like hysteresis occurring upon cooling below 5 K [1]. We performed electron spin resonance (ESR) spectroscopy measurements in wide frequency and temperature ranges to explore the dynamic magnetic properties of $MnBi_4Te_7$. From high-frequency ESR measurements, we obtain evidence that $MnBi_4Te_7$ is an easy-axis type ferromagnet and ferromagnetic spin correlations persist up to T = 30 K on the time scale of an ESR experiment (10^{-10} - 10^{-11} s). [1] Raphael C. Vidal et. al, Topological electronic structure and intrinsic magnetization in $MnBi_4Te_7$: a Bi_2Te_3-derivative with a periodic Mn sublattice, arXiv:1906.08394.

MA 7.7 Mon 11:00 POT 6

Spin orbit torque with topological insulator and ferro/antiferromagnetic heterostructures — •sumit ghosh[1,2] and aurelien manchon[2] — [1]PGI-1 and IAS-1, Forschungszentrum, Jülich 52425, Germany — [2]PSE, King Abdullah University of Science and Technology, Thuwal 23955, Saudi Arabia

Due to the robust spin-orbit coupling emerging at the surfaces, topological insulators like Bi2Se3 have become a strong source of spin-orbit torque [1,2]. However in the vicinity of a magnetic element the topological protection and hence the interfacial spin-orbit coupling change drastically. In this presentation, we are going to see some of the interesting phenomena arising at the interface of a topological insulator and ferro/antiferromagnet heterostructure [3,4]. Using a simplified tight binding model we are going to show how the interfacial spin texture is modified in the presence of a magnetic element and its impact on the non-equilibrium spin density within the linear response framework. We show how the non-equilibrium spin density changes while moving from surface dominated regime to bulk dominated regime. We also explain the origin of the large spin-Hall angle for the topological insulator ferromagnet heterostructure. Finally, we show their robustness against the scalar impurity to demonstrate their superiority against their heavy metal counterpart.

[1] A. R. Mellnik et. al., Nature, 511, 449 (2014).
[2] D. C. Mahendra et. al. Nature Materials, 17, 800 (2018).
[3] S. Ghosh and A. Manchon, Phys. Rev. B 97, 134402 (2018).
[4] S. Ghosh and A. Manchon, Phys. Rev. B 100, 014412, (2019).

MA 7.8 Mon 11:15 POT 6

Magneto-electrically controllable spin-orbit torque in topological insulator thin films — •Ali G. Moghaddam[1,2], Alireza Qaiumzadeh[3], Anna Dyrdal[4,2], and Jamal Berakdar[2] — [1]Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan 45137-66731, Iran — [2]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, D-06099 Halle, Germany — [3]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [4]Faculty of Physics, Adam Mickiewicz University, ul. Umultowska 85, 61-614 Poznan, Poland

We investigate the inverse spin-galvanic effect (ISGE) in topological insulator thin films and the resulting spin-orbit torque (SOT) in the hybrid structures with magnetic layers. Considering in-plane magnetizations inside the magnetic layers which can shift the Dirac dispersion of surface states in the two sides, we find anisotropic ISGE and SOT with a strong dependence on the chemical potential and the magnetization. Then the magnetization-dependence of current-induced spin densities gives rise to a nonlinear field-like SOT which can be controlled by varying the magnetization and applying external gate voltages to change the chemical potential. Also, the mathematical relations between current-induced spin densities and the conductivity of this system results in similar anisotropic features in the magneto-conductance of TI thin film.

MA 8: Ultrafast Electron Dynamics I: Surfaces and Interfaces (joint session O/MA)

Time: Monday 10:30–13:15 Location: TRE Phy

MA 8.1 Mon 10:30 TRE Phy

Electron dynamics of surface states in momentum space on Cu and Au — •Lukas Hellbrück, Tobias Eul, Martin Aeschlimann, and Benjamin Stadtmüller — Department of Physics and Research Center Optimas, University of Kaiserslautern, Germany

For the development of nanoscale electronic and spintronic devices, it is critical to understand electronic dynamics in solid states systems and at interfaces. Of particular interest is the correlation between the energy and momentum dissipation mechanisms of the hot carriers and the band structure of the material.

In this work, we employ time-resolved two photon momentum microscopy [1] with monochromatic radiation of about 4.6eV to access the electron dynamics in the excited state energy range of typical noble metal surfaces. From these data, we can extract momentum dependent quasi-particle lifetimes of the electrons, providing insight into momentum dependent scattering processes in these materials.

We focus on the (111) and (110) low-index copper and gold surfaces. These surfaces yield a variety of different states in the unoccupied band structure ranging from resonant and off-resonant bulk transitions to Shockley surface states and image potential states. For these different types of states, we observe lifetime differences of several femtoseconds, which points to a complex momentum dependent lifetime of the electrons, even for simple single crystalline materials.

[1] F. Haag et al., Rev. Sci. Instr. 90, 103104 (2019)

MA 8.2 Mon 10:45 TRE Phy

Above-threshold multiphoton photoemission from noble metal surfaces — •Marcel Reutzel[1,2], Andi Li[2], and Hrvoje Petek[2] — [1]I. Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, USA

Exciting solid surfaces with intense femtosecond laser pulses prompts electrons of the interrogated material to respond in highly non-linear manner, as is evident in the emission of high-order harmonic radiation and photoelectrons with kinetic energies well above that of the driving photons (above threshold photoemission, ATP). In the solid state, the optical field interacts with the electronic eigenstates defined by the Coulomb potential of a periodic crystal, as well as with its many-body screening response.

In this contribution, we probe the nonlinear photoelectric responses of the pristine silver surfaces in (111) and (110) crystal orientation using interferometrically time-resolved multi-photon photoemission spectroscopy. First, we study the coherent electron dynamics leading to non-resonant coherent mPP of the occupied Shockley surface band of Ag(111). We characterize and benchmark the two-dimensional Fourier transform (2D-FT) spectra based on the photoemission order m and the coherences induced in the sample (m = 2-6) [Phys. Rev. X 9, 01104545 (2019)]. Second, we show that ATP can be used to probe deep points in the Brillouin zone, namely the surface state of Ag(110) at the $\bar{Y}$-point, that is otherwise hidden below the photoemission horizon in lowest order of mPP.

MA 8.3 Mon 11:00 TRE Phy

Interfacial carrier and phonon dynamics in nanostructured metal/2D-semiconductor plasmonic heterostructures — •Tommaso Pincelli[1], Thomas Vasileiadis[1], Shuo Dong[1], Samuel Beaulieu[1], Maciej Dendzik[1], Daniela Zahn[1], Sang-Eun Lee[1], Hélène Seiler[1], Yinpeng Qi[1], Patrick Xian[1], Julian Maklar[1], Emerson Coy[2], Niclas Müller[3], Yu Okamura[3], Stephanie Reich[3], Martin Wolf[1], Laurenz Rettig[1], and Ralph Ernstorfer[1] — [1]Fritz-Haber-Institut der MPG, Berlin, Germany — [2]NanoBioMedical Centre, Adam Mickiewicz University, Poznan, Poland — [3]Freie Universität Berlin, Berlin, Germany

Noble metal nanostructures enhance light absorption in semiconductors to produce plasmons, whose decay couples strongly with the generation of hot carriers and non-equilibrium phonons. We combine the use of time and angle-resolved photoemission spectroscopy and femtosecond electron diffraction to investigate both charge carrier and phonon dynamics in a plasmonic metal/semiconductor heterostructure.

We grow epitaxial Au nanoislands on single-crystalline bulk WSe_2. The presence of Au nanostructures causes a shortening of the Σ-exciton lifetime and an accelerated lattice heating of WSe_2, which indicate interfacial charge transfer. Furthermore, we observe a non-equilibrium phonon distribution in WSe_2 with sub-bandgap optical pumping, demonstrating increased sensitivity of the semiconductor to near infrared frequencies. The corresponding energy transfer scales nonlinearly with the incident laser fluence, owing to plasmonically-enhanced phonon excitation.

MA 8.4 Mon 11:15 TRE Phy

Ultrafast hole-transfer in $MoSe_2/WSe_2$ revealed by polarisation dependent second-harmonic imaging microscopy — •Jonas Zimmermann, Ulrich Höfer, and Gerson Mette — Fachbereich Physik, Philipps-Universität Marburg, Germany

Charge transfer across heterointerfaces plays a fundamental role for the functionality of electronic devices. 2D heterostructures based on transition metal dichalcogenides (TMDC) with their wide variety of materials and stacking combinations represent a unique opportunity for systematic studies of the interfacial charge-carrier dynamics.

Here, we present results on a $MoSe_2/WSe_2$ heterostructure investigated by time-resolved second-harmonic (SH) imaging microscopy. The transient SH-response after resonant optical excitation reveals a delayed filling and an enhanced lifetime for the heterostructure which is absent for the individual monolayers, indicating the formation of interlayer excitons. By careful selection of the polarisation of the probe laser, we are able to enhance the sensitivity to the individual layers in the heterostructure and with that to the charge transfer. Systematic measurements in dependence of the pump photon energy and the probe polarisation exhibit temporal signatures which are attributed to hole transfer from WSe_2 to $MoSe_2$ and vice versa with transfer times of a few hundred femtoseconds in both cases.

MA 8.5 Mon 11:30 TRE Phy

Electron transfer dynamics in MoS_2 imaged by time-resolved momentum microscopy — •Lasse Münster[1], Sarah Zajusch[1], Katsumi Tanimura[2], Jens Güdde[1], Robert Wallauer[1], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Germany — [2]Institute of Scientific and Industrial Research, Osaka

University, Japan

We investigate the electron dynamics in the topmost layer of MoS_2 after optical excitation above the A-exciton resonance by means of time- and angle-resolved two-photon photoemission with a high harmonic probe. High harmonic generation in krypton is used to produce an almost isolated 7^{th} harmonic of the 400 nm driving laser pulses at a repetition rate of 200 kHz. This is combined with tunable pump pulses in the visible range for resonant excitation. The photoemitted electrons are detected by a momentum microscope with time of flight detection that covers the full photoemission horizon in a single measurement. With a high harmonic probe this results in the imaging of the entire first Brillouin zone in TMDCs.

We observe an instantaneous occupation of the conduction band after optical excitation at all $\overline{\mathrm{K}}$-points followed by an ultrafast transfer to the conduction band minima at $\overline{\Sigma}$. For longer delays the excited electron distribution localizes at these high symmetry points which we attribute to electron cooling. The real-space imaging capability of the momentum microscope allows the restriction of such experiments to micrometer-size regions which opens up the possibility to observe momentum-resolved charge transfer in TMDC heterostructures.

MA 8.6 Mon 11:45 TRE Phy

Ultrafast electron dynamics in black phosphorus studied by time-resolved photoemission momentum microscopy — •Maciej Dendzik[1,2], Shuo Dong[1], Tommaso Pincelli[1], Samuel Beaulieu[1], Patrick Xian[1], Helene Seiler[1], Martin Wolf[1], Laurenz Rettig[1], and Ralph Ernstorfer[1] — [1]Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6, 14915 Berlin, Germany — [2]KTH Royal Institute of Technology, Electrum 229, 164 40 Kista, Sweden

Black phosphorus (BP) has recently emerged as a promising material due to its highly anisotropic thermal, electronic and optical properties. The high hole mobility together with a band-gap tunable by thickness in the visible to mid-IR range make BP attractive for future applications in opto-electronics. Therefore, detailed information on both the equilibrium and excited-state electronic band structure of BP is of strong interest. Here we present a fs time-resolved study of transient electronic structure of BP in the entire surface Brillouin zone (SBZ) directly imaged with a momentum microscope using a novel setup for XUV time- and angle-resolved photoemission spectroscopy. The measured dispersion is found to be in good agreement with density functional theory calculations. We find that an optical excitation at 800 nm creates a hot-carrier distribution around the SBZ center, which scatters to two other valleys in the conduction band within ca. 15 fs. We further observe a strong linear dichroism in the optical absorption of BP. Interestingly, the inter-valley scattering dynamics are also found to depend on the pump polarization vector direction.

MA 8.7 Mon 12:00 TRE Phy

Carrier dynamics in a laser-excited Fe/(MgO)(001) heterostructure from real-time TDDFT — •Elaheh Shomali, Markus Ernst Gruner, and Rossitza Pentcheva — Department of Physics and Center for Nanointegration, CENIDE, University of Duisburg-Essen, Germany

The interaction of a femtosecond optical pulse with a metal/oxide interface has been addressed based on time-dependent density functional theory (TDDFT) in the real-time domain using the Elk code. We systematically studied electronic excitations of a $Fe_1/(MgO)_3(001)$ heterostructure as a function of laser frequency, peak power density and polarization direction. We find a marked anisotropy in the response to in-plane and out-of-plane polarized light, which changes its character for frequencies lower and higher than the MgO band gap. For laser frequencies between the MgO band gap and the charge transfer gap, interface states resulting from the hybridization of the $d_{3z^2-r^2}$ orbitals of Fe and the p_z orbitals of O at the interface may foster the propagation of excitations into the central layer of MgO. Spin-orbit coupling (SOC) is found to result in a small time-dependent reduction of magnetization only. Finally, we extend our investigation to thicker heterostructures, such as $Fe_3/(MgO)_5(001)$.

Financial support from the DFG within SFB 1242 (project C02) is gratefully acknowledged.

MA 8.8 Mon 12:15 TRE Phy

Local and non-local electron dynamics of Au/Fe/MgO(001) heterostructures analyzed by time-resolved two-photon photoemission spectroscopy — Yasin Beyazit[1], Jan Beckord[1], Ping Zhou[1], Jan Philipp Meyburg[2], Detlef Diesing[2], Manuel Ligges[1], and •Uwe Bovensiepen[1] — [1]University of Duisburg-Essen, Faculty of Physics and Center for Nanointegration (CENIDE), 47048 Duisburg) — [2]University of Duisburg Essen, Faculty of Chemistry, Universitätsstr. 5, 45711 Essen

The ultrafast electron dynamics at interfaces is determined by the competition of local scattering processes and transport effects. Employing femtosecond laser pulses in front and back side pumping of Au/Fe/MgO(001) [1] combined with detection in two-photon photoelectron emission spectroscopy we analyze local relaxation dynamics of excited electrons in buried Fe, injection into Au across the Fe-Au interface, and electron transport across the Au layer at 0.6 to 2.0 eV above the Fermi energy. By analysis as a function of Au film thickness we obtain the electron lifetimes of bulk Au and Fe and distinguish the relaxation in the heterostructure's constituents. We conclude further that electron injection across the epitaxial interface proceeds by electron wavepacket propagation. We also show that the excited electrons propagate through Au in a superdiffusive regime determined by few e-e scattering events. Application of such back side pumping photoelectron spectroscopy to further material systems will be discussed. Funding by the DFG through CRC 1242 is gratefully acknowledged.

[1] Alekhin et al., J. Phys. Condens. Matter 31, 124002 (2019)

MA 8.9 Mon 12:30 TRE Phy

Time-resolved nonlinear optical spectroscopy of ultrafast charge transfer at the buried GaP/Si(001) interface — •Gerson Mette[1], Jonas Zimmermann[1], Alexander Lerch[1], Kristina Brixius[1], Jens Güdde[1], Andreas Beyer[1], Michael Dürr[2], Kerstin Volz[1], Wolfgang Stolz[1], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Germany — [2]Institut für Angewandte Physik, Justus-Liebig-Universität Giessen, Germany

The ongoing miniaturization increases the contribution of interface processes to electronic device properties. For a microscopic understanding, the dynamics of charge transfer across interfaces are particularly important. However, due to the experimental difficulty to detect and isolate the weak interface signature from the dominant bulk signals, direct experimental information about the ultrafast dynamics at buried interfaces is scarce.

Here, we will show that the experimental challenges can be overcome by optical second-harmonic generation (SHG), a technique which is intrinsically highly interface sensitive. We are investigating the ultrafast charge-carrier dynamics at the buried interface of GaP on Si(001) by time-resolved optical-pump SHG-probe spectroscopy. Photon energy dependent measurements reveal the existence of electronic interface states in the band gap of both materials. Charge carriers excited via these interface states are efficiently injected within a few hundred femtoseconds from the GaP/Si interface into the Si substrate resulting in the build-up of an electric field on a picosecond time scale.

MA 8.10 Mon 12:45 TRE Phy

Pump-probe second harmonic spectroscopy of molecule/metal interfaces — Jinghao Chen, Ping Zhou, Uwe Bovensiepen, and •Andrea Eschenlohr — Faculty of Physics, University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Achieving a microscopic understanding of charge transfer dynamics and the relaxation of optically excited electrons and holes at molecule/metal interfaces requires an interface-sensitive analysis on the respective femtosecond timescales. Second harmonic spectroscopy (SHS) [1] is such an interface-sensitive probe in centrosymmetric materials. We employ a non-collinear optical parametric amplifier in the visible wavelength range (1.9-2.5 eV) for pump-probe SHS with <20 fs pulse duration. A prototypical molecule/metal interface is prepared by adsorption of iron octaethylporphyrin (FeOEP) molecules on Cu(001) [2] and analyzed *in situ* in ultrahigh vacuum. We find a molecule-induced resonance at about 2.2 eV fundamental photon energy in the second harmonic spectrum of one monolayer of FeOEP/Cu(001). At this resonance, we observe a markedly slower relaxation time of the pump-induced changes in SHS compared to the bare Cu(001) surface, which indicates an increased lifetime of the electronic molecular state.

We thank H. Wende, J. Güdde and E. Riedle for valuable experimental advice, and the German Research Foundation for funding via SPP 1840 QUTIF and Sfb 1242.

[1] T. F. Heinz, C. K. Chen, D. Ricard, and Y. R. Shen, Phys. Rev. Lett. **48**, 478 (1982); U. Höfer, Appl. Phys. A **63**, 533 (1996).

[2] H. C. Herper et al., Phys. Rev. B **87**, 174424 (2013).

MA 8.11 Mon 13:00 TRE Phy

Dynamics of interfacial electron-hole separation in an organic heterojunction monitored by femtosecond time-resolved X-ray photoelectron spectroscopy — •Friedrich Roth[1], Mario Borgwardt[2], Lukas Wenthaus[3], Johannes Mahl[2], Steffen Palutke[4], Günter Brenner[4], Serguei Molodtsov[1,5], Wilfried Wurth[3,4,6], Oliver Gessner[2], and Wolfgang Eberhardt[3] — [1]Institute of Experimental Physics, TU Bergakademie Freiberg, Leipziger Straße 23, D-09599 Freiberg, Germany — [2]Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA — [3]Center for Free-Electron Laser Science / DESY, D-22607 Hamburg, Germany — [4]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22603 Hamburg, Germany — [5]European XFEL GmbH, Holzkoppel 4, 22869, Schenefeld, Germany — [6]Universität Hamburg, Luruper Chaussee 149, 22761, Hamburg, German

The dynamics of ultrafast photon-to-charge conversion in a copper-phthalocyanine (CuPc)-C_{60} heterojunction is studied by femtosecond time-resolved X-ray photoemission spectroscopy (tr-XPS) at the free-electron laser FLASH. The technique provides site-specific access to electron dynamics and monitors the generation and decay of interfacial charge-transfer (ICT) states after excitation with 775 nm photons. A previously unobserved channel for ICT separation into mobile charge carriers with an efficiency of 22 ± 7 % is identified, providing a direct measure of the internal quantum efficiency of the heterojunction for this channel.

MA 9: Weyl Semimetals

Time: Monday 11:30–13:15 Location: POT 6

MA 9.1 Mon 11:30 POT 6

Strong Correlations in Pyrochlore-Iridates based on the example of Y2IrO7 — •Johannes Graspeuntner — TU Graz, Österreich

Pyrochlore-Iridates have attracted some attention after being proposed to host topological non-trivial states. In this talk we will investigate one example of this class of materials, namely Y2IrO7, and study the effect of strong electronic correlations on the electronic structure. We will investigate the validity of one-band description using only the effective j=1/2 states around the Fermi energy, as compared to a complete treatment of the full t2g shell, where a closer look is taken on the AIAO magnetic ordering on the frustrated Pyrochlore lattice. Furthermore, we will discuss short-ranged non-local correlation effects via a cluster-DMFT treatment.

MA 9.2 Mon 11:45 POT 6

Quadrupolar Weyl metal in magnetically ordered pyrochlore iridates — •Konstantinos Ladovrechis[1], Bitan Roy[2,3], and Tobias Meng[1] — [1]Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [3]Department of Physics, Lehigh University, Bethlehem, Pennsylvania 18015, USA

Pyrochlore iridates are a class of materials in which the confluence of electronic interactions and emergent topology leads to a plethora of exotic states of matter. In this work, we study an effective low-energy Luttinger model accounting for a quadratic band touching (QBT) around the Γ point, and study interaction-induced instabilities of the QBT. In particular, we analyze the impact of a new type of magnetic order transforming under the T_{2u} irreducible representation of the cubic point group. This magnetic order is of octupolar character. It breaks time-reversal symmetry but is inversion-invariant, and thus for example stabilized quadrupoles of Weyl points on different planes in the Brillouin zone. By classifying these unconventional electronic structures, we comment on experimental signatures of this new magnetic order in itinerant pyrochlore iridates, for example in transport experiments.

MA 9.3 Mon 12:00 POT 6

Spin, angle and time-resolved photoemission studies of WTe_2 — •J. Schusser[1,2], L. Nicolaï[1], M. Fanciulli[2,3], M.-i Lee[2], Z. El Youbi[2,4], M. C. Richter[2], O. Heckmann[2], D. Bresteau[3], T. Ruchon[3], K. Hricovini[2], and J. Minár[1] — [1]NTC, U. of West Bohemia, Czech Republic — [2]LPMS, U. of Cergy-Pontoise, France — [3]ATTOLab, CEA, France — [4]DLS, Harwell Campus, United Kingdom

Mo dichalcogenides are probably the most studied TMDCs by virtue of being appealing for various possible reasons suchlike spin or valley pseudospin and their interactions. W-based counterparts are on the other hand evincing much stronger spin-orbit coupling due to which all the spin-related effects are more stable at room temperature and thus more feasible for application. WTe_2, the type-II Weyl semimetal candidate is in particular interesting due to the possibility of having spin-differentiated Weyl points above Fermi energy. We have conducted several pump-probe experiments following the evolution of the band dispersion in the vicinity of X and Y points of WTe_2 and TR-SARPES experiments in the part of Brillouin zone where the presence of Weyl points is predicted. The study was supported by Ab-initio one-step model photoemission calculations using SPR-KKR package and compared to experiment the remarkable agreement of which helps us to disentangle the subsequent relaxation processes. We have also conducted a preliminary band structure calclulations of $HfTe_2$ revealing the high potential of SPR-KKR package for calculating the band dispersion of layered materials by including geometry effects of the experiment as well as the polarization and energy of the incoming light.

MA 9.4 Mon 12:15 POT 6

Spin and orbital texture of the Weyl semimetal $MoTe_2$ studied by spin-resolved momentum microscopy — •Kenta Hagiwara[1], Xin Liang Tan[1], Philipp Rüssmann[1], Ying-Jiun Chen[1,2], Koji Fukushima[3], Keiji Ueno[3], Vitaliy Feyer[1], Shigemasa Suga[4,1], Stefan Blügel[1], Claus M. Schneider[1,2], and Christian Tusche[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich — [2]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg — [3]Department of Chemistry, Saitama University, 338-8570, Saitama, Japan — [4]ISIR, Osaka University, 567-0047, Osaka, Japan

Weyl semimetals host chiral fermions in solids as a pair of non-degenerate linear dispersions with band crossing points in bulk. These Weyl points are protected by crystal symmetry, forming a Fermi arc, which is a connection between a pair of Weyl points with opposite chirality at the surface. Momentum microscopy provides two dimensional photonelectron maps of the in-plane crystal momentum over the whole Brillouin zone, simultaneously. Together with an imaging spin filter, we have revealed the spin-resolved electronic structure of the type-II Weyl semimetal $1T_d$ $MoTe_2$ in the full Brillouin zone. Combined with the use of differently polarized light, we have revealed the spin texture and the orbital texture of the Weyl cones in comparison with first-principles calculations. We give evidence that a pair of Weyl cones exhibits a strong circular dichroism with reversed sign, indicating the different charge of the respective Weyl points in the Fermi surface.

MA 9.5 Mon 12:30 POT 6

Unconventional Fermi arcs in an ultrathin complex magnet — •Ying-Jiun Chen[1,2], Jan-Philipp Hanke[1,3], Markus Hoffmann[1,3], Gustav Bihlmayer[1,3], Yuriy Mokrousov[1,3,4], Stefan Blügel[1,3], Claus M. Schneider[1,2], and Christian Tusche[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, D-52425 Jülich — [2]Fakultät für Physik, Universität Duisburg-Essen, D-47057 Duisburg — [3]Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich — [4]Institute of Physics, Johannes Gutenberg University Mainz, D-55099 Mainz

The discovery of topological states of matter has led to a revolution in materials research. When external or intrinsic parameters break certain symmetries, global properties of topological materials change drastically. A paramount example is the emergence of Weyl nodes under broken inversion symmetry, acting like magnetic monopoles in momentum space. In this talk, we demonstrate that under broken time-reversal symmetry open Fermi arcs appear at the surface of the complex magnet 2 ML Fe/W(110). Our spin- and orbital-resolved momentum microscopy experiments together with density functional theory give evidence that the Fermi-surface topology of the atomically thin ferromagnet is substantially modified by the hybridization with a heavy-metal substrate, giving rise to Fermi-surface discontinuities being bridged by the Fermi arcs. The hybridization points are attributed to a non-trivial "mixed" topology and induce hot spots in the Berry curvature, dominating spin and charge transport as well as magnetoelectric coupling effects.

MA 9.6 Mon 12:45 POT 6

Infrared spectroscopy on the magnetic Weyl-semimetal $\mathbf{Co_3Sn_2S_2}$ — •Felix Schilberth[1,2], Franz Mayr[1], Joachim Deisenhofer[1], Hiroyuki Nakamura[3], Mohamed Kassem[3], Sándor Bordács[2], and István Kézsmárki[1,2] — [1]Chair for Experimental Physics V, University of Augsburg, 86159 Augsburg, Germany — [2]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary — [3]Department of Materials Science and Engineering, Kyoto University, Kyoto 606-8501, Japan

We investigate the shandite $Co_3Sn_2S_2$, a ferromagnet with kagome lattice and a magnetic ordering temperature of 174 K. According to recent angle resolved photoemission spectroscopy (ARPES) studies, the bulk band structure of this material hosts Weyl-nodes and correspondingly the surface states form so-called Fermi arcs. Since the Fermi-Energy lies in the vicinity of the Weyl-nodes, large anomalous Hall-effect (AHE) was detected in $Co_3Sn_2S_2$. Here, we use infrared spectroscopy to uncover the low-energy electronic excitations of this compound. Regarding the kagome plane, our data reflects the anisotropy of the crystal structure for polarisations in- and out-of-plane. For both polarisations, the magnetic ordering causes a reconstruction of the electronic states in the vicinity of the Fermi-Energy. In addition, we investigate the spin dependent properties of the bands using magneto-optical Kerr-effect (MOKE) spectroscopy in the infrared-visible energy range. From these experiments, we determine both the diagonal and the off-diagonal parts of the conductivity tensor which allow us to identify the key features of the band structure responsible for the large AHE.

MA 9.7 Mon 13:00 POT 6

Giant anomalous Hall and Nernst effect in magnetic cubic Heusler compounds — •Jonathan Noky[1], Yang Zhang[2], Claudia Felser[1], and Yan Sun[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Massachusetts Institute of Technology, Cambridge, USA

There is an ongoing search for materials with large anomalous Hall and Nernst effects. These effects can be utilized in applications for data storage, thermoelectric power generation, and a high temperature quantum anomalous Hall effect, when preparing them as thin films. A promising class of materials for this purpose are the Heusler compounds because they can be grown in thin films and have a high Curie temperature. In these systems, the interplay between magnetism and topological band structures leads to a strongly enhanced Berry curvature. This can consequently create large anomalous Hall and Nernst effects.

In this work, we provide a comprehensive study of the intrinsic anomalous transport properties for magnetic cubic full Heusler compounds and we illustrate that several Heusler compounds outperform the best so far reported materials. Additionally, the results reveal the general importance of mirror planes in combination with magnetism for giant anomalous Hall and Nernst effects, which should be valid for all linear responses (spin Hall effect, spin orbital torque, etc.) dominated by intrinsic contributions.

MA 10: Focus Session: Spin-Charge Interconversion (joint session MA/HL)

While classical spintronics has traditionally relied on ferromagnetic metals as spin generators and spin detectors, a new approach called spin-orbitronics exploits the interplay between charge and spin currents enabled by the spin-orbit coupling (SOC) in non-magnetic systems. Efficient spin-charge interconversion can be realized through the direct and inverse Edelstein effects at interfaces where broken inversion symmetry induces a Rashba SOC. Although the simple Rashba picture of split parabolic bands is usually used to interpret such experiments, it fails to explain the largest conversion effects and their relation to the actual electronic structure.

Organizer: Ingrid Mertig (University Halle-Wittenberg)

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

Invited Talk MA 10.1 Mon 15:00 HSZ 04

SrTiO3-based 2-dimensional electron gases for ultralow power spintronics — •Manuel Bibes — CNRS/Thales, Palaiseau, France

The MESO transistor is a spin-based non-volatile device proposed by Intel in which magnetic information is written by a magnetoelectric element and read out by a spin-orbit element through the inverse spin Hall effect or the inverse Edelstein effect (IEE). In this talk, I will show that the 2DEG that forms at the interface of SrTiO3 (STO) with LaAlO3 or reactive metals such as Al may be exploited to interconvert spin and charge currents through the direct and inverse Edelstein effects with high efficiencies. I will first present spin to charge conversion experiments using the spin-pumping technique to inject a spin current in the 2DEG. By applying a gate voltage, we tune the position of the Fermi level in the multi-orbital electronic structure of STO, which results in a strong variation of the IEE amplitude with sign changes. This can be modelled through a tight-banding modelling of the band structure measured by ARPES. Importantly, a finite conversion effect persists at room temperature, with a figure-of-merit competitive for MESO-based electronics. In a second part, I will present gate-controlled, all-electrical spin current generation and detection in planar nanodevices free from ferromagnets and only based on a STO 2DEG. Here, the spin current is generated by the direct 2D spin Hall effect from a charge current running in the 2DEG, transported through the device over several microns and reconverted into a charge current by the inverse 2D spin Hall effect.

Invited Talk MA 10.2 Mon 15:30 HSZ 04

Spin-to-charge current conversion for logic devices — •Felix Casanova — CIC nanoGUNE, San Sebastian, Basque Country, Spain

The integration of logic and memory in spin-based devices, such as the recent MESO proposal by Intel [1], could represent a post-CMOS paradigm. A key player is the spin Hall effect (SHE), which allows to electrically create or detect pure spin currents without using ferromagnets (FM). Understanding the different mechanisms giving rise to SHE allows to find and optimize promising materials for an efficient spin-to-charge conversion (SCC). We unveiled these mechanisms in prototypical materials Pt and Ta [2]. A radically different approach is by engineering a van der Waals heterostructure which combines graphene with a transition metal dichalcogenide. We recently demonstrated SHE in graphene due to spin-orbit proximity with MoS2 [3]. The combination of long-distance spin transport and SHE in different parts of the same material gives rise to an unprecedented SCC efficiency.

Finally, I will present a novel and simple FM/Pt nanodevice to readout the in-plane magnetic state of the FM electrode using SHE [4]. The spin-orbit based detection allows us to independently enhance the output voltage (needed to read the in-plane magnetization) and the output current (needed for cascading circuit elements) with downscaling of different device dimensions, which are necessary conditions for implementing the MESO logic [1].

[1] Manipatruni et al., Nature 565, 35 (2019); [2] Sagasta et al., PRB 94, 060412 (2016); ibid. 98, 060410 (2018); [4] Safeer at al., Nano Lett. 19, 1074 (2019); [5] Pham et al., submitted.

Invited Talk MA 10.3 Mon 16:00 HSZ 04

Spin-charge interconversion in graphene/TMD Van der Waals heterostructures — •Bart Van Wees — Zernike Institute for Advanced materials, University of Groningen, The Netherlands

I will give an introduction into spin transport, spin relaxation and spin-charge conversion in Van der Waals heterostructures made of (single) layer graphene and (single layer) transition metal dichalcogenides (TMDs). Due to their proximity, the strong anisotropic spin orbit interaction in the TMD results in anisotropic, valley-Zeeman and Rashba type spin orbits field in the graphene . As a result the spin relaxation in graphene becomes strongly anisotropic, with out-of-plane oriented spins having a factor 10 or more longer spin life times than in-plane oriented spins [1,2]. The proximity induced spin orbit interaction also gives the possibility of gate tuneable spin change interconversion mechanisms such as spin Hall effect (and its inverse) and Rashba Edelstein effect (and its inverse). I will explain how these effects are observed experimentally [3,4,5], and how they can be optimized for future 2D spintronics applications.

1] T.S. Ghiasi et al., Nano Lett. 17, 7528-7532 (2017)
2] L.Benitez et al., Nature Physics 14, pages303-308(2018)
3] C.K. Safeer et al., Nano Lett. 19, 2, 1074-1082 (2019)
4] T.S. Ghiasi et al., Nano Lett. 19,9, 5959-5966 (2019)
5] L. A. Benítez et al, https://arxiv.org/abs/1908.07868

15 min. break.

Invited Talk MA 10.4 Mon 16:45 HSZ 04

Ferroelectric control of the spin-to-charge conversion in the ferroelectric Rashba semiconductor GeTe — Sara Varotto[1], Luca Nessi[1], Stefano Cecchi[2], Paul Noel[3], Simone Petrò[1], Alessandro Novati[1], Raffaella Calarco[2], Matteo Cantoni[1], Laurent Vila[3], Jean-Philippe Attané[3], Riccardo Bertacco[1], and •Christian Rinaldi[1] — [1]Dipartimento di Fisica, Politecnico di Milano, via Colombo 81, 20133 Milano, Italy — [2]Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany — [3]Univ. Grenoble Alpes, CNRS, CEA, Grenoble INP, IRIG-SPINTEC, F-38000 Grenoble, France

Scalable and energy efficient spin-orbit logic has been very recently pointed out by Intel as technologically suitable computing alternative to CMOS devices [1]. It comprises an electrically driven memory element, with the spin-orbit-based detection of the state performed by spin-to-charge conversion. In this talk, we show that the ferroelectric Rashba semiconductor Germanium Telluride offers memory as well as spin-orbit readout in a silicon-compatible semiconductor. GeTe possesses a giant bulk Rashba-like spin texture, which can be reversed by its non-volatile ferroelectricity [2]. Here we demonstrate the switchability of bulk GeTe through gate electrodes, enabling the electric control of spin textures. Spin pumping measurements in Fe/GeTe heterostructures revealed the ferroelectric control of the spin to charge conversion, paving the way to single-compound spin-orbit logic devices.

[1] S. Manipatruni, Nature 565, 35 (2019); [2] C. Rinaldi et al., Nano Letters 18, 2751 (2018)

Invited Talk MA 10.5 Mon 17:15 HSZ 04

Theory of spin-to-charge conversion in a topological oxide two-dimensional electron gas — •Annika Johansson[1], Börge Göbel[1,2], Ingrid Mertig[1], and Manuel Bibes[3] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]Unité Mixte de Physique CNRS/Thales, Université Paris-Sud, Université Paris-Saclay, Palaiseau, France

$SrTiO_3$ (STO)-based two-dimensional electron gases (2DEGs) provide a highly efficient spin-to-charge conversion [1], also known as inverse Edelstein effect [2,3]. Recently, an extremely large spin-to-charge conversion efficiency was demonstrated in the 2DEG at the interface between STO and Al [4]. The application of a gate voltage leads to a strong variation and even sign changes of the spin-to-charge conversion.

We explain this unconventional gate dependence of the (inverse) Edelstein effect from a theoretical perspective by Boltzmann transport calculations within a multiorbital tight-binding model. By a band-resolved analysis of the Edelstein signal we relate the experimentally observed spin-to-charge conversion to the band structure as well as the topological character and the spin texture of the 2DEG.

[1] E. Lesne *et al.*, Nat. Mater. **15**, 1261 (2016)
[2] V. M. Edelstein, Solid State Commun., **73**, 233 (1990)
[3] K. Shen *et al.*, Phys. Rev. Lett. **112**, 096601 (2014)
[4] D. Vaz *et al.*, Nature Materials **18**, 1187 (2019)

Invited Talk MA 10.6 Mon 17:45 HSZ 04

Nonlinear magnetoresistance from surface states of a topological insulator — •Giovanni Vignale[1], Pan He[2], Dapeng Zhu[2], Shuyuan Shi[2], Hyunsoo Yang[2], Steven S.-L Zhang[3,4], and Olle Heinonen[3] — [1]Department of Physics and Astronomy, University of Missouri-Columbia, Missouri 65211, USA — [2]1Department of Electrical and Computer Engineering, and NUSNNI, National University of Singapore, 117576, Singapore — [3]2Materials Science Division, Argonne National Laboratory, Lemont, Illinois 60439, USA — [4]3Department of Physics, Case Western Reserve University, Cleveland, Ohio 44106, USA

Surface states of topological insulators exhibit the phenomenon of spin-momentum locking, whereby the orientation of an electron spin is determined by its momentum. We have discovered a close link between the spin texture of these states and a new type of nonlinear magnetoresistance, which depends on the relative orientation of the current with respect to the magnetic field as well as the crystallographic axes, and scales linearly with both the applied electric and magnetic fields. The nonlinear magnetoresistance originates from the conversion of a non-equilibrium spin current into a charge current under the application of an external magnetic field. Additionally, we find that the transverse component of the nonlinear resistance exhibits a pi/2 phase shift with respect to its longitudinal counterpart, in marked contrast to the usual pi/4 phase difference that exists between the linear planar Hall effect and the anisotropic magnetoresistance in typical topological insulators and transition metal ferromagnets.

MA 11: Bio- and Molecular Magnetism (joint session MA/CPP)

Time: Monday 15:00–17:00 Location: HSZ 101

MA 11.1 Mon 15:00 HSZ 101

HF-EPR investigations on Co(II)- and Fe(IV)-coordination complexes — •Lena Spillecke[1], Changhyun Koo[1], Shalini Tripathi[2], Maheswaran Shanmugam[2], Saskia Krieg[3], Peter Comba[3], and Rüdiger Klingeler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Department of Chemistry, Indian Institute of Technology, Mumbai, India — [3]Institute of Inorganic Chemistry, Universität Heidelberg, Heidelberg, Germany

We present high-frequency/high-field electron paramagnetic resonance (HF-EPR) studies on Co(II) and Fe(IV) coordination complexes. For Co(II) systems, we show that ligand exchange in the 2nd coordination sphere on $[Co(L_1)_4]X_2$, with L_1 = thiourea (NH_2CSNH_2) and X = I (**1**),Br (**2**), SiF6 (**3**)) has significant effects on the crystal field and hence on magnetic anisotropy of the Co-ion. While the substitution of I by Br only has small impact on the axial anisotropy (D = -153(2)/-168(5) GHz, respectively), we observed strong enhancement of anisotropy in the SiF_6 containing sample ($|D| > 800$ GHz). Furthermore, our data enables precise determination of weak intermolecular coupling in the range of several hundred mK which sign changes by ligand substitution. In additon, we present HF-EPR data on an octahedrally coordinated Fe(IV)-complex which was prepared under liquid N_2 conditions. Our results confirm the intermediate-spin state and detect axial anisotropy of $D = 107(3)$ GHz.

MA 11.2 Mon 15:15 HSZ 101

Magnetic field tuning of low energy spin dynamics in the single-atomic magnet $Li_2(Li_{1-x}Fe_x)N$ with $x \ll 1$ — •Sascha Albert Bräuninger[1], Sirko Kamusella[1], Felix Seewald[1], Rajib Sarkar[1], Manuel Fix[2], Stephan Jantz[2], Anton Jesche[2], Andre Zvyagin[3], and Hans-Henning Klauss[1] — [1]Institute of Solid State and Materials Physics, TU Dresden, D-01069 Dresden, Germany — [2]Institute of Physics, University Augsburg, D-86135 Augsburg, Germany — [3]Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Str., 38, D-01187 Dresden, Germany

We present a systematic ^{57}Fe-Mössbauer study on highly diluted Fe centers in $Li_2(Li_{1-x}Fe_x)N$ single-crystals as a function of temperature and magnetic field applied transverse and longitudinal with respect to the single-ion anisotropy axis. Below 30 K the Fe centers exhibit a giant magnetic hyperfine field of $\bar{B}_A = 70.25(2)$ T parallel to the axis of strongest electric field gradient $\bar{V}_{zz} = -154.0(1)\,\mathrm{V/Å^2}$. Fluctuations of the magnetic hyperfine field are observed between 50 K and 300 K and described by the Blume two-level relaxation model. An Arrhenius analysis yields a single thermal activation barrier of $\bar{E}_A = 570(6)$ K. Mössbauer spectroscopy studies with applied transverse magnetic fields up to 5 T reveal a large increase of the fluctuation rate by more than one order of magnitude. The experimental observations are qualitatively reproduced by a single-ion effective spin Hamiltonian analysis assuming a Fe^{1+} d^7 charge state with unquenched orbital moment and a $J = 7/2$ ground state.

MA 11.3 Mon 15:30 HSZ 101

Intramolecular crossover from 2D diamagnetism to 3D paramagnetism — •Carolin Schmitz-Antoniak[1], Alevtina Smekhova[2], Detlef Schmitz[2], Natalya V. Izarova[1], S. Fatemeh Shams[1], Maria Stuckart[3], Frank M. F. de Groot[4], and Paul Kögerler[1,5] — [1]Forschungszentrum Jülich (PGI-6), 52425 Jülich — [2]Helmholtz-Zentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin — [3]Inst. f. Chem. Reaktionstechnik, FAU Erlangen-Nürnberg, 91058 Erlangen — [4]Inorganic Chemistry and Catalysis Group, Debye Inst. for Nanomaterials Science, Utrecht University, Utrecht 3584 CG — [5]Inst. f. Anorgan. Chemie, RWTH Aachen University, 52074 Aachen

In a 2D square-planar coordination with four surrounding oxygen anions, Pd(II) ions in polyoxopalladates are diamagnetic with a large orbital contribution to the magnetic response as revealed by XANES and XMCD. Supported by atomic multiplet calculations the dependence of electronic and magnetic properties on 4d spin-orbit coupling, bond lengths, and delocalization of 4d electrons was investigated. We found that (i) four additional out-of-plane oxygen anions around Pd(II) lead to an effective 3D symmetry causing a paramagnetic response in external magnetic fields and (ii) in the crossover region between common diamagnetism and paramagnetism, the large spin-orbit coupling of Pd facilitates an unusual diamagnetic state modified by significant mixing. Furthermore, by measuring and analysing characteristic fine structures of the diamagnetic states in the XMCD spectrum, we overcome the common limitation of XMCD to ferro/ferrimagnetic and paramagnetic materials in external magnetic fields.

MA 11.4 Mon 15:45 HSZ 101

Chemical Doping of Individual Polynuclear Molecular Magnets on Surfaces — •Fabian Paschke[1], Vivien Enenkel[1], Tobias Birk[1], Jan Dreiser[2], and Mikhail Fonin[1] — [1]Fachbereich Physik, Universitaet Konstanz, 78457 Konstanz, Germany — [2]Swiss Light Source, 5232 Villigen PSI, Switzerland

The controlled deposition, characterization and manipulation of single molecule magnets (SMMs) on surfaces is one of the crucial topics to investigate with regard to their possible implementation as units in future electronic and spintronic devices. Fe_4 derivatives are among the most investigated SMMs showing a giant spin and a variety of quantum mechanical phenomena. We showed that a flat derivative of this SMM is suitable for defined adsorption on decoupling monatomic layers of *h*-BN and graphene [1,2]. We proved the robust molecular magnetism to be retained on a global and single molecule scale, even on metallic substrates [2-4]. In order to manipulate electronic and magnetic properties of individual SMMs chemical doping with alkali atoms has shown to be a feasible technique [5]. Unfortunately, large polynuclear compounds like Fe_4 can host numerous adsorption sites for dopants. Here we present successful chemical doping with a defined adsorption configuration for the prototypical Fe_4 SMM and study the effect on its electronic and magnetic properties.

[1] P. Erler et al., Nano Lett. 15, 4546 (2015). [2] L. Gragnaniello et al., Nano Lett. 17, 7177 (2017). [3] F. Paschke et al., ACS Nano 13, 780 (2019). [4] F. Paschke et al., *submitted* (2019). [5] C. Krull et al., Nat. Mat. 12, 337 (2013).

MA 11.5 Mon 16:00 HSZ 101

Numerical Challenges in Studying Families of 3*d*-4*f* Heterometallic Single-Molecule Magnets — •Julius Mutschler[1], Hetti M. Jayawardena[1], Christopher E. Anson[2], Annie K. Powell[2], and Oliver Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Institut für anorganische Chemie, Universität Karlsruhe, KIT, Germany

The discovery of slow relaxation and quantum tunneling of the magnetization in single molecule magnets (SMMs) has inspired both physicists and chemists alike. This class of molecules has been expanded to heterometallic clusters incorporating transition metal and rare earth ions. The 4*f* ions are of interest because of their large angular momentum and magnetic anisotropy, but present unexpected challenges in the numerical analysis of experimental powder susceptibility and magnetization curves. For example in the case of the 3*d*-4*f* SMM Mn_2Ho_2-square, the dimension of the Hilbert space is 7225, and the computation time for a full exact diagonalization is only few 10 seconds. However, when fitting the powder magnetization with a 10 parameter model, which is typical for this type of molecules, ca 10^7 diagonalizations need to be performed, resulting in an impractical total time for completing the fit of several years. In this talk our approaches to tackle this challenge are demonstrated.

MA 11.6 Mon 16:15 HSZ 101

Dy2O-clusterfullerenes: Strong magnetic anisotropy and fullerene-dependent single molecule magnetism — •Georgios Velkos[1], Wei Yang[2], Stanislav Avdoshenko[1], Ning Chen[2], Bernd Büchner[1], and Alexey Popov[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]College of Chemistry, Soochow University, Suzhou, China

The exceptional ability of fullerenes to stabilize species which can hardly exist otherwise has been extensively used to create a number of endohedral metallofullerene families. Among them, there is a great interest in Dy-metallofullerenes, caused by their robust magnetic properties. In this work, we report on the synthesis and in-depth magnetic study of the first Dy2O-clusterfullerenes. The compact geometry of Dy2O cluster leads to both strong axial ligand field and unprecedentedly strong antiferromagnetic exchange coupling between Dy ions. We demonstrate that Dy2O-clusterullerenes are excellent molecular magnets exhibiting broad magnetic hysteresis and the strongest super-exchange coupling between Dy ions ever reported for non-radical bridged compounds.

MA 11.7 Mon 16:30 HSZ 101

Dynamic magnetic response of a single Magnetite nanoparticle chain detected by Scanning Transmission X-Ray Microscopy Ferromagnetic Resonance — •Thomas Feggeler[1], Benjamin Zingsem[1,2], Ralf Meckenstock[1], Michael Winklhofer[3], Detlef Spoddig[1], Hendrik Ohldag[4], Michael Farle[1], Heiko Wende[1], and Katharina Ollefs[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Lotharstr. 1, Duisburg, Germany — [2]ERC and PGI, Fz. Jülich GmbH, Jülich, Germany — [3]School of Mathematics and Science, University of Oldenburg, Oldenburg, Germany — [4]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA, United States

The dynamic magnetization of a single nanoparticle chain of 19 Magnetite particles (diameter of about 50 nm) embedded in a bacterium Magnetospirillum Magnetotacticum is measured using Scanning Transmission X-Ray Microscopy detected Ferromagnetic Resonance (STXM-FMR) [1]. A resonant response of the segments of the nanoparticle chain is identified and confirmed by micromagnetic simulations. STXM-FMR features the element specific detection of magnetization dynamics with a spatial resolution $<$ 50 nm and a time resolution in the ps regime. The manipulation of the genetic code of the bacteria allows to control the arrangement of the nanoparticles leading to the creation of magnonic logic devices as a future concept for magnonic computing [2]. [1] S. Bonetti, et al., Rev. Sci. Instrum. 86 (2015). [2] B. W. Zingsem, et al., Nat. Commun. 10 (2019). Financial support: FWF Project I-3050, ORD-49, DFG Project 321560838.

MA 11.8 Mon 16:45 HSZ 101

Biologically encoded magnonics — •Benjamin Zingsem[1], Thomas Feggeler[1], Ralf Meckenstock[1], Michael Farle[1], and Michael Winklhofer[1,2] — [1]University Duisburg-Essen — [2]Universität Oldenburg

We report on the spectral properties of spin-waves (magnons) in individual chains of dipolar coupled magnetite nanoparticles. The particle-chains are biologically produced in magnetotactic bacteria. Straight chains where obtained from wild-type, curved and looped chains form mutant bacteria. A strong link between distinct spectral properties of the chains and their geometrical arrangement is identified, paving the way towards genetically engineered spin-wave computing on the nanoscale. Each chain consists of ca. 12 nanoparticles with a diameter of about 30 nm, separated by a spacing of about 8 nm. Ferromagnetic resonance spectroscopy was employed to measure the magnonic Eigenstates of each single particle in the chain as a function of the magnitude and direction of an applied magnetic field. The measurements are supplemented with micromagnetic simulations, which reveal the origin of spectral features such as band repulsion and attraction in resonant eigenstates. The emergent topology of the spin-wave band structure exhibits functional properties such as band deflection and band deformation, which may be harnessed in energy efficient magnon computing [1] and neuro-inspired magnonic networks. Future nanomagnonic devices may be self-assembled via genetic engineering of magnetotactic bacteria.

[1] B. Zingsem, et al. Nat Commun 10, 4345 (2019)

MA 12: Multiferroics (joint session KFM/MA)

Time: Monday 15:00–17:40 Location: HSZ 105

MA 12.1 Mon 15:00 HSZ 105

Magnetoelectric crystals as model systems of quantum optics — •Janek Wettstein[1], Andrei Pimenov[1], Alexander A. Mukhin[2], Artem Kuzmenko[2], Kirill Amelin[3], Toomas Rõõm[3], Urmas Nagel[3], and David Szaller[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [3]National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618 Tallinn, Estonia

The interaction between an ensemble of non-interacting two-level quantum systems and a bosonic field is theoretically described by the Dicke-model which predicts a quantum phase transition in the thermodynamic limit when the strength of the interaction reaches a sufficiently large critical value [1,2]. Here, based on the idea of Ref. [3] we present a method to study the superradiant phase transition in $SmFe_3(BO_3)_4$, where isolated rare-earth quasi-spins (Sm) play the role of the two-level system and the bosonic field is provided by the spin-waves (i.e. magnons) of the antiferromagnetically ordered Fe ions. At low temperatures ($T = 3\,K$) we observe an avoided crossing of the optically active low-frequency iron magnon and the Sm quasispin excitations with a coupling of about 70% of the critical value needed for the superradiant transition. The strength of the coupling was tuned by varying density and population of the Sm two-level systems.

[1] K. Hepp and E. H. Lieb, Phys. Rev. A 8, 2517 (1973).
[2] Y. K. Wang and F. T. Hioe, Phys. Rev. A 7, 831 (1973).
[3] X. Li et al., Science 361, 794 (2018).

MA 12.2 Mon 15:20 HSZ 105

Strain-Driven Metal-to-Insulator Transition and Charge Ordering in LiV2O4 — Yu-Mi Wu, Ulrike Niemann, Yi Wang, Y. Eren Suyolcu, Minu Kim, Hidenori Takagi, and •Peter A. van Aken — Max Planck Institute for Solid State Research, Stuttgart, Germany

The coupling of local atomic configurations and electronic degrees of freedom plays a fundamental role in understanding metal-insulator transitions and the formation of charge ordering. In particular, such competing interactions become more pronounced in the geometrically frustrated pyrochlore lattice in the spinel structure, due to fluctuations in the charge, spin and orbital channels. By STEM imaging and electron energy-loss spectroscopy, we have investigated mixed-valence spinel LiV2O4 thin films grown on SrTiO3 and MgO (001) substrates. The epitaxial strain strongly affects the spatial configurations of valence states in LiV2O4, and the local valence distributions are resolved at atomic-scale resolution. Two competing phases are detected in the thin films, a metallic charge-disordered heavy-fermion state on SrTiO3 and an insulating charge-ordered state on MgO. Importantly, our result shows that the out-of-plane lattice compression relieves the charge frustration and induces a Verwey-type-like charge-ordering pattern in LiV2O4. This observation provides atomic-scale insight into the strong charge-order correlation and tuneable electronic-phase transitions in related frustrated systems. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 823717 - ESTEEM3.

MA 12.3 Mon 15:40 HSZ 105

Investigation of multiferroic coupling in $Ca_3Mn_{1.9}Ti_{0.1}O_7$ by optical second harmonic generation — •Yannik Zemp[1], Mads Weber[1], Thomas Lottermoser[1], Morgan Trassin[1], Bin Gao[2], Sang-Wook Cheong[2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich — [2]Rutgers University, New Jersey

Layered perovskite materials, such as $A_3B_2O_7$ Ruddlesden-Popper compounds, are under scrutiny in the search for multiferroics with a strong magnetoelectric coupling and large polarisations at high temperatures. Their crystal structure allows for the implementation of a wide range of magnetic ions and it can be host to geometrically induced ferroelectricity. For $Ca_3Mn_2O_7$, theory predicts a robust magnetoelectric coupling between the improper ferroelectricity and the Mn^{3+} magnetism, mediated by the MnO_6-octahedra tilts. However, experimental evidence is still pending. Here, we investigate such a possible coupling in $Ca_3Mn_{1.9}Ti_{0.1}O_7$. We probe the influence of the magnetic ordering on the ferroelectricity using second harmonic generation (SHG) - a non-invasive, highly symmetry-sensitive laseroptical technique ideal for the study of ferroic order. We observe a strong increase in the SHG signal upon entering the magnetic phase, which indicates a strong influence of the magnetism on the ferroelectricity. Measurements of the SHG spectrum and images of the domain pattern suggest a coupling of the magnetic order to the polarisation mechanism via the octahedral tilts. Our results demonstrate that layered perovskites are promising candidates in search for multiferroics with pronounced magnetoelectric coupling.

MA 12.4 Mon 16:00 HSZ 105

Magnetic Structure and Magnetoelectricity in Holmium-Doped Langasite — •Lukas Weymann[1], Thomas Kain[1], Lorenz Bergen[1], Alexey Shuvaev[1], Evan Constable[1], David Szaller[1], Artem M. Kuzmenko[2], Alexander A. Mukhin[2], Vsevolod Yu. Ivanov[2], Nadezhda V. Kostyuchenko[1,3], Maxim Mostovoy[4], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria — [2]Prokhorov General Physics Institute of Russian Academy of Sciences, Moscow, Russia — [3]Moscow Institute of Physics and Technology, Dolgoprudny, Moscow region, Russia — [4]Theory of Condensed Matter, Zernike Institute for Advanced Materials, Groningen, The Netherlands

The compounds of the rare-earth langasite family R3Ga5SiO14 were investigated for their striking electromechanical properties in the early 1980s and attracted new scientific attention due to their intriguing magnetic and magnetoelectric properties in the past decade. In this work we present the results of a magnetoelectric effect, i.e. electric polarization induced by an external magnetic field, in the diluted holmium langasite.

This effect has an unusual angular dependence, which can be explained by taking into account the three-fold symmetry of the crystal and its rather complex magnetic structure. The latter was investigated by measurements in a Vibrating Sample Magnetometer and a torque magnetometer. Magnetic and magnetoelectric results can be understood taking into account the interplay between crystal symmetry and the local symmetry of the Holmium ions.

20 min. break

MA 12.5 Mon 16:40 HSZ 105

Non-invasive study of buried domain patterns in multiferroic bismuth ferrite — •Marvin Müller[1], Yen-Lin Huang[2], Ramamoorthy Ramesh[2], Morgan Trassin[1], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland — [2]University of California, Berkeley, USA

Magnetoelectric (ME) multiferroic materials hosting coexisting and coupled electric and magnetic orders allow for low-energy control of magnetism and thus hold great promise for energy-efficient random-access memories and logic devices. In $BiFeO_3/Co_{0.9}Fe_{0.1}$ heterostructures, room-temperature electric-field-induced reversal of the ferromagnetic magnetization has been recently achieved. Despite extensive studies on the ME coupling in $BiFeO_3$, the switching dynamics remain elusive. The lack of direct experimental access to the ferroic properties of the buried material renders *operando* investigations challenging. Here, we probe the ferroelectric switching in the model system $BiFeO_3/Co_{0.9}Fe_{0.1}$. We use spatially-resolved non-invasive optical second harmonic generation (SHG) to map the net polarization of the buried $BiFeO_3$ layer after voltage application. Our results suggest the emergence of a strong net polarization with the first voltage pulse. Additional scanning probe microscopy is used to correlate this observation with the emergence of stripe-domain patterns with 71° domain walls. This work introduces SHG as an effective tool to non-invasively study buried ferroelectric domain states and thus opens novel pathways towards *operando* electro-optic studies on the dynamics in these coupled systems.

MA 12.6 Mon 17:00 HSZ 105

B-site doping effects in multiferroic rare-earth hexagonal manganites — •Marcela Giraldo[1], Martin Lilienblum[1], Hasung Sim[2], Lea Forster[1], Je-Geun Park[2], Thomas Lottermoser[1], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland. — [2]Seoul National University, Korea.

Chemical doping is an alternative to tailor the properties of complex oxides. A–site doping in hexagonal $R\mathrm{MnO_3}$ with Ca or Zr leads to a conductivity enhancement at the domain walls while preserving the characteristic topological ferroelectric state of the system. Stronger effects on the magnetism in this multiferroic family are expected by doping at the B–site. This is due to the direct perturbation of the magnetic sublattices formed by Mn^{3+} moments. We investigate Al-doping (0-25%) at the B–site in h-$YMnO_3$. We use a combination of second-harmonic generation (SHG) and piezoresponse force microscopy to disclose the effects on antiferromagnetic and ferroelectric domain formation. The later ones, for example, reveal a size decrease with increasing degree of doping. Furthermore, a combination of SHG and X-ray diffraction (XRD) unveils a decreasing trend for magnetic/electric ordering temperatures as a function of doping. This is due to the chemical pressure induced by the distinct ionic sizes of Al and Mn and the progressive decomposition of the long-range order. By tracing the changes in the inherent properties of these ferroic systems, we aim to broaden the understanding for new routes in the manipulation of this important class of multiferroics.

MA 12.7 Mon 17:20 HSZ 105

Excitations and switching dynamics in RMn2O5 — Louis Ponet[1,2], •Sergey Artyukhin[1], Maxim Mostovoy[3], and Andrei Pimenov[4] — [1]Italian Institute of Technology, Genova, Italy — [2]Scuola Normale, Pisa, Italy — [3]University of Groningen — [4]TU Wien

RMn2O5 manganites have attracted significant attention due to the complex interplay between Mn and rare earth orders, resulting in multiferroic phases and peculiar excitations. Here we perform model and first-principles simulations to analyze excitations and peculiar switching dynamics in these compounds.

MA 13: Frustrated Magnets - General 2 (joint session TT/MA)

Time: Monday 15:00–16:00 Location: HSZ 304

MA 13.1 Mon 15:00 HSZ 304

Quantum domain wall induced incommensurate magnetic phase in frustrated Ising model — •Zheng Zhou[1], Zheng Yan[1,2], Dong-Xu Liu[3], Yan Chen[1,4], and Xue-Feng Zhang[5] — [1]Department of Physics and State Key Laboratory of Surface Physics, Fudan University, Shanghai 200438, China — [2]Department of Physics, The University of Hong Kong, Hong Kong, China — [3]Department of Physics, Chongqing University, Chongqing, 401331, China — [4]Collaborative Innovation Center of Advanced Microstructures, Nanjing 210093, China — [5]Department of Physics, and Center of Quantum Materials and Devices, Chongqing University, Chongqing, 401331, China

We study the AFM Ising model with transverse field h and NNN Ising interaction J' on triangular lattice, which describes the magnet $TmMgGaO_4$. Between the known clock and stripe phase at weak and moderate J', an incommensurate order may emerge due to the interplay between quantum fluctuation and geometrical frustration. In particular, the proliferation of quantum domain walls (DW) may stabilize such a novel phase. Numerical calculation of DW density and peaks of structure factor at certain positions provides evidence for this phase. Furthermore, we study its dynamical spectrum, which can be measured by neutron refraction. At a low h, we found a low-lying mode which agrees well with the behavior of DWs. At the h level of $TmMgGaO_4$, this mode merges with a high-lying mode corresponding to KT physics. We suggest that in materials with smaller splitting, distinct DW modes as strong evidence of this phase may be observed.

MA 13.2 Mon 15:15 HSZ 304

Non-Hermitian Topology of Spontaneous Magnon Decay — •Paul McClarty[1] and Jeff Rau[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]University of Windsor, Ontario, Canada

I will briefly review recent progress on topological magnons placing particular emphasis on the effects of magnon-magnon interactions on the bulk and the boundary magnons. We show that the effects of interactions on single magnon states can often be recast in terms of an energy-independent non-Hermitian Hamiltonian. The spectral function has a characteristic anisotropy, in the vicinity of magnon touching points, arising from topologically protected exceptional points or lines in the non-Hermitian spectrum. This is, in principle, detectable using inelastic neutron scattering.

[1] P.A. McClarty and J. G. Rau, Phys. Rev. B 100, 100405(R) (2019)

MA 13.3 Mon 15:30 HSZ 304

Tuning the two-step melting of magnetic order in dipolar kagome ice by quantum fluctuations — Yao Wang[1,2], •Stephan Humeniuk[1], and Yuan Wan[1,2] — [1]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — [2]University of Chinese Academy of Sciences, Beijing 100049, China

Complex magnetic orders in frustrated magnets may exhibit rich melting processes when the magnet is heated toward the paramagnetic phase. We show that one may tune such melting processes by quantum fluctuations. We consider a kagome lattice dipolar Ising model subject to transverse field and focus on the thermal transitions out of its magnetic ground state, which features a $\sqrt{3}\times\sqrt{3}$ magnetic unit cell. Our quantum Monte Carlo simulations suggest that, at weak transverse field, the $\sqrt{3}\times\sqrt{3}$ magnetic order melts by way of an intervening, magnetically charge ordered phase where the lattice translation symmetry is restored whilst the time reversal symmetry remains broken. By contrast, at strong transverse field, quantum Monte Carlo simulations suggest the $\sqrt{3}\times\sqrt{3}$ order melts through a floating Kosterlitz-Thouless phase. The two distinct melting processes are likely separated by a multicritical point.

MA 13.4 Mon 15:45 HSZ 304

Nematic correlations in the coupled J1-J2 chains — •Clio Efthimia Agrapidis[1], Stefan-Ludwig Drechsler[2], and Satoshi Nishimoto[1,3] — [1]Faculty of Physics, University of Warsaw — [2]Institute for theoretical solid state physics, IFW Dresden — [3]Department of Physics, Technical University Dresden

It is known that the ferromagnetic frustrated J_1-J_2 chain is a good minimal model for several cuprate chain materials. Moreover, this model exhibits multipolar physics in magnetic field. Motivated by this, we study antiferromagnetically coupled J_1-J_2 chains: the interchain coupling J' is considered to vary from pure Ising to Heisenberg exchange by varying the XXZ anisotropy parameter Δ. In general, the interchain coupling can act as an effective magnetic field. When J' is Ising-like, the system exhibits a fully magnetised state for $J'/|J_1| > 1$. This magnetisation might be related to the existence of a nematic state. Remarkably, the system shows finite magnetisation also in the limit of Heisenberg interchain coupling.

MA 14: General Spintronics

Time: Monday 15:00–18:15 Location: HSZ 401

MA 14.1 Mon 15:00 HSZ 401

Tunable magnetic anisotropy energy with quantum well state in $SrRuO_3$ — •Angus Huang[1], Horng-Tay Jeng[1,2,3], and Ching-Hao Chang[4,5] — [1]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan — [2]Physics Division, National Center for Theoretical Sciences, Hsinchu 30013, Taiwan — [3]Institute of Physics, Academia Sinica, Taipei 11529, Taiwan — [4]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan — [5]Center for Quantum Frontiers of Research & Technology (QFort), National Cheng Kung University, Tainan 70101, Taiwan

We demonstrate theoretically the magnetic anisotropy in $SrRuO_3$ thin film can be well controlled by geometrical and electrical modulations: the easy axis (preferred magnetization direction) can be switched between perpendicular and parallel to the film either by slightly altering the film thickness or by moderately doping electrons. Such an ability is given by the spin-polarized quantum well states (QWSs) near the Fermi level. The QWSs are susceptible to the intrinsic spin orbital interaction and thus drive a large energy discrepancy when a $SrRuO_3$ thin film rotates its magnetization direction. As a result, the low-energy magnetic state can be fine controlled by varying the QWS energy positions via geometry or electricity. The significances of this phenomenon are illustrated in the thin films by the large anisotropy energy induced by the spin-polarized quantum-well resonances, and by the ideal electric control of the easy axis.

MA 14.2 Mon 15:15 HSZ 401

Modelling phonon-driven spin-relaxation in organic semiconductors from first-principles — •Uday Chopra[1,2], Sergei Egorov[1,3], Jairo Sinova[1], and Erik R. McNellis[1] — [1]Johannes Gutenberg University, Staudingerweg 7, Mainz, 55128 — [2]Max Planck Graduate Centre, Mainz, Germany — [3]University of Virginia, Chemistry Department, McCormick Rd, Charlottesville, VA 22901 USA

Spin-orbit coupling (SOC) is one of the major causes of spin-relaxation in organic semiconductors. As SOC itself does not conserve energy, relaxation is caused in conjunction with external factors, for example a hopping driven spin-flip mechanism [1,2]. In this work, we explore local and non-local spin-relaxation caused due to molecular vibrations. We present a model to estimate the spin-phonon couplings using finite-differences within harmonic approximation from a first-principles approach. Using these couplings we are able to derive the spin-relaxation times (T1) between the Zeeman energy levels for Raman-like processes using Fermi's Golden rule. Our model assumes a relaxation mediated via two phonons via an intermediate state. This enables us to analyse the relevant phonon-modes that dominate the relaxation in addition to evaluating the temperature dependence of T1. We present our findings using organic-semiconductors and single-molecule magnets to demonstrate transferability across different systems. [1] Chopra et al. Phys. Rev. B 100, 134410 (2019) [2] Chopra et al. J. Phys. Chem. C 123, 19112, (2019)

MA 14.3 Mon 15:30 HSZ 401

Highly compliant planar Hall effect sensors — •Rico Illing, Tobias Kosub, Pablo Granell, Eduardo Sergio Oliveros Mata, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung

Shapeable magnetoelectronics [1] is an integral part of prospective measurement technology for consumer electronics, medical appliances and entertainment electronics including smart textiles and electronic skins [2]. Especially for medical applications, the sensitivity of the contemporary flexible magnetic field sensors should be substantially improved to the level of 1 nT or even below. Planar Hall effect (PHE) sensors are exceptionally suited for reaching this ambitious goal. In this respect, rigid PHE sensors reveal sensitivity of 5 pT [3]. Here, we present a highly compliant magnetic field sensor based on the planar Hall effect prepared on ultrathin polymeric foils. By optimizing the sensor design and measurement methodology, we boost the sensitivity of the PHE sensors to sub-10 nT, which is more than an order of magnitude improvement compared to the state of the art devices [4]. [1] D. Makarov et al., Appl. Phys. Rev. 3, 011101 (2016). [2] J. Ge et al., Nature Communications 10, 4405 (2019). [3] N. Nhalil et al., IEEE Sensors Letters 3, 2501904 (2019). [4] P. Granell et al., npj Flexible Electronics 3, 3 (2019).

MA 14.4 Mon 15:45 HSZ 401

Spin transport phenomena in vertical spin valves with spacer layers consisting of layered tetragonal $FeGe_2$ — •Dietmar Czubak, Samuel Gaucher, Jens Herfort, Holger Grahn, and Manfred Ramsteiner — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

The formation of $FeGe_2$ in a layered tetragonal structure has been recently achieved by solid-phase epitaxy of Ge on Fe_3Si. This thin polymorphic film of $FeGe_2$ does not exist in bulk form and appears to be a promising material for spintronic applications. We investigate vertical spin valve structures, in which $FeGe_2$ serves as a spacer layer between the two ferromagnetic Heusler alloy films Fe_3Si and Co_2FeSi. The spin valves exhibit magnetoresistances up to 0.3%, originating from the switching between parallel and antiparallel magnetization orientations of the ferromagnetic electrodes. This spin valve effect becomes larger with increasing thickness of the spacer layer, which can be explained by a non-dissipative tunneling process dominating the transport through the $FeGe_2$ spacer layer. Additionally, we observe inverted spin valve-like signals by rotating the in-plane direction of the external magnetic field, which are attributed to a tunneling anisotropic magnetoresistance (TAMR). With decreasing temperature, both, the spin valve and the TAMR signals, become smaller and exhibit a correlation with a ferromagnetic phase transition in the $FeGe_2$ layer. These results constitute a crucial step towards the understanding of the fundamental properties of layered $FeGe_2$ films.

MA 14.5 Mon 16:00 HSZ 401

Noise-driven magnetic spin dynamics for an insulating Heisenberg magnet coupled to a metallic lead — •Benjamin F. McKeever[1], Karin Everschor-Sitte[1], and Kei Yamamoto[2] — [1]Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany — [2]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai 319-1195, Japan

Near interfaces between a magnet and a non-magnetic metal, Gilbert damping in magnetic spin dynamics is enhanced due to spin-dependent scattering of conduction electrons. The enhancement corresponds to a transfer of spin angular momentum into the normal metal from the magnet (spin pumping), with strength determined by the spin mixing conductance. Similarly, the reciprocal effect, where spin-angular momentum is transferred into the ferromagnet from the normal metal, is pertinent when applying an electric current (Slonczewski spin-transfer torque). To go beyond the paradigm of magneto-electric circuit theory which defines the mixing conductance, and to tie together the different relevant effects, we investigate the role of interface-induced noise fluctuations in the spin dynamics; this is done by modelling the coupling between the normal metal conduction electron spin density and magnetic insulator spins with sd exchange interaction for any kind of magnetic spin system. Ferromagnetic and antiferromagnetic spin chains are presented as example applications of the resulting stochastic LLG equation, which is accurate up to second order in the sd exchange. The formalism presents a way to address interface-driven nonequilibrium noise effects in heterostructures with thin magnetic layers.

MA 14.6 Mon 16:15 HSZ 401

Evidence for Magnetic Polarons in the Ferromagnetic Semiconductor $HgCr_2Se_4$? – A Fluctuation Spectroscopy Study — •Merlin Mitschek[1], Shuai Yang[2], Yongqing Li[2], and Jens Müller[1] — [1]Institute of Physics, Goethe-University, Frankfurt (Main), Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing, China

Semiconducting $HgCr_2Se_4$ is a member of the spinel family of compounds where one can observe a colossal magnetoresistance (CMR) effect, a field of research that expanded the knowledge of electronic correlations, phase transitions and magnetism. The complexity of the physics underlying the CMR makes it desirable to study a preferably simple system, where the relevant degrees of freedom, including spin, charge, orbital and lattice, along with disorder and strong electron correlations are less intertwined. A typical model system is EuB_6 [1] and also $HgCr_2Se_4$, where the phase transition from the paramagnetic to the ferromagnetic phase coincides with an insulator-to-metal transition at $T_C \approx 105$ K. The CMR effect [2] is found to strongly depend on the degree of disorder in the samples. In our noise measurements, we find $1/f^{\alpha}$-type fluctuation spectra from room temperature down to low temperatures. The normalized resistance noise power spectral density (PSD) increases by nearly two orders of magnitude upon approaching T_C. For $100\,\mathrm{K} < T < 150\,\mathrm{K}$, we observe superimposed Lorentzian spectra originating in single two-level processes. We discuss our findings in terms of a model of percolating magnetic polarons.

[1] PRB **86**, 184425, [2] PRB **94**, 224404.

MA 14.7 Mon 16:30 HSZ 401

Magnon transport in three-terminal magnetically ordered insulator/platinum nanostructures — •Janine Gückelhorn[1,2], Tobias Wimmer[1,2], Sudhir Regmi[3], Arunava Gupta[3], Stephan Geprägs[1], Hans Huebl[1,2,4], Rudolf Gross[1,2,4], and Matthias Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]University of Alabama, Center for Materials for Information Technology MINT and Department of Chemistry, Tuscaloosa, AL, USA — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

The transport of information via spin waves (magnons) in magnetically ordered insulators provides novel routes for information processing. We present our results of the transport of magnons in the ferrimagnetic insulators (FMI) nickel ferrite (NFO), and yttrium iron garnet (YIG). In our experiments, we deposit three electrically isolated platinum (Pt) strips on top of our FMI thin films. The outer Pt strips act as spin current injector and detector. The center strip is utilized to modulate the magnon transport via a charge current. In the injector and modulator strip the charge current flow controls the magnon density in the FMI via the spin Hall effect and thermal Joule heating. We systematically study the magnon transport in NFO and YIG as a function of applied magnetic field and temperature. Moreover, we compare these results to simultaneous spin Hall magnetoresistance measurements.

Financial support by the DFG (AL2110/2-1) is acknowledged.

15 min. break.

MA 14.8 Mon 17:00 HSZ 401

Resistivity of bulk tetragonal CuMnAs at finite temperatures from the first principles — •David Wagenknecht[1,2], Karel Výborný[3], Karel Carva[1], and Ilja Turek[1,2] — [1]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Prague, Czechia — [2]Institute of Physics of Materials, The Czech Academy of Sciences, Brno, Czechia — [3]Institute of Physics, The Czech Academy of Sciences, Prague, Czechia

From the first principles, we investigate antiferromagnetic CuMnAs and its finite-temperature electrical transport [1]. It is primary motivated by spintronic applications, such as electrical switching of its magnetic moments, and by testing of novel ab initio codes. Tetragonal bulk CuMnAs was prepared recently [2], which opened a possibility to measure the out-of-plane resistivity. Explaining temperature-dependent electrical transport is a challenging task for ab initio calculation. For this purpose, we employ our implementation of the alloy analogy model based on the coherent potential approximation, previously used, e.g., to study half-Heusler NiMnSb [3]. Because of antiferromagnetic character of CuMnAs, there are many specifics in the description of both magnons and phonons; above that, we will discuss a role of chemical impurities. Three models of magnetic disorder and a combined effect with other scattering phenomena will be shown [1]. Last but not least, our approach is reliable and it reproduces the experimental data.

[1] D. Wagenknecht et al. Submitted to JMMM (October 2019) [2] K. Uhlířová et al. J. Alloys Compd. 771 680-685 (2019) [3] D. Wagenknecht et al. PRB 99 174433 (2019)

MA 14.9 Mon 17:15 HSZ 401

Modeling of current induced switching in Mn2Au — •Severin Selzer[1], Leandro Salemi[2], András Deák[3], Eszter Simon[3], Karel Carva[4], László Szunyogh[3], Peter M. Oppeneer[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, DE-78457 Konstanz, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Department of Theoretical Physics, Budapest University of Technology and Economics, H-1111 Budapest, Hungary — [4]Department of Condensed Matter Physics, Charles University, Ke Karlovu 5, CZ 121 16 Prague, Czech Republic

Mn2Au is a promising candidate as material for future antiferromagnetic spintronic devices, since its order parameter can be switched by 90 degree via electric currents [1]. The switching mechanism relies on the Edelstein effect that gives rise to induced magnetic moments, which in Mn2Au are staggered due to the broken inversion symmetry.

We model the current-induced switching within the framework of atomistic spin dynamics simulations based on a multiscale approach were the parameters for the spin model as well as for the Edelstein effect were calculated from first principles [2]. Within this model, we explore the mechanism and the time scales involved in the switching process.

[1] J. Železný, P. Wadley, K. Olejník, A. Hoffmann, and H. Ohno, Nature Physics 14, 220 (2018).

[2] L. Salemi, M. Berritta, A. K. Nandy, and P. M. Oppeneer, Nat Commun 10, 1 (2019).

MA 14.10 Mon 17:30 HSZ 401

Transport characterization of individual hemispherical shells by zero-offset Hall magnetometry — •Eduardo Sergio Oliveros Mata[1], Tobias Kosub[1], Oleksii M. Volkov[1], Oleksandr Pylypovskyi[1,2], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Magnetic thin films exhibit novel anisotropic and chiral effects driven by local curvatures. In this context, various curvilinear effects have been studied in theoretical and experimental works [1]. Typically, magnetic properties are assessed based on integral measurements or relying on advanced microscopy characterization. Spintronic studies of individual curvilinear magnetic nanoobjects are missing, primarily due to the low adaptability of standard lithographic processes to integrate with 3D submicron objects. Here, we apply zero-offset Hall magnetometry [2] to carry out electron transport measurements of curvilinear nanostructures. We test the viability of the technique by comparing the transport characteristics between flat nanodisks and individual hemispherical nanoshells in magnetic vortex and hedgehog states. This approach is relevant to perform both fundamental characterization of curved magnetic architectures and direct integration of these structures in magnetic sensorics.

[1] R. Streubel, et al., J. Phys. D: Appl. Phys. 49, 363001 (2016) [2] T. Kosub, et al., PRL 115, 097201 (2015)

MA 14.11 Mon 17:45 HSZ 401

Ab-initio calculations of transport properties of doped permalloy: exploring the effect of the host disorder — •Ondrej Sipr[1,2], Sebastian Wimmer[3], Sergey Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics, Czech Academy of Sciences, Praha — [2]NTC, University of West Bohemia, Pilsen, Czech Republic — [3]Ludwig-Maximilians-Universität München, Germany

The transport properties of permalloy $Fe_{0.19}Ni_{0.81}$ (Py) doped with V, Co, Pt, and Au have been explored by evaluating the Kubo-Bastin formula within the ab-initio KKR Green function framework, both for zero and for finite temperatures. It is demonstrated that the fact that the Py host is not crystalline but randomly disordered has profound consequences. Transverse conductivities characterizing the anomalous Hall effect (AHE) and the spin Hall effect (SHE) are found to be not proportional to the longitudinal conductivity for low dopant concentrations; consequently, the dependence of the AHE and SHE on the dopant concentration cannot be unambigously ascribed to skew scattering, side-jump scattering, or intrinsic contributions in the same way as it can be done for a crystalline host.

Several relationships between quantities are considered. The longitudinal charge conductivity decreases with increasing dopant concentration and the rate of this decrease depends on the dopant type, following the sequence Co-Au-Pt-V, in accordance with the scattering properties of each atom type. The dependence of the AHE and SHE conductivities on the dopant concentration is found to be nonmonotonic and strongly dependent on the temperature.

MA 14.12 Mon 18:00 HSZ 401

High-throughput screening for ferromagnetic intermetallics with giant anomalous Hall/Nernst conductivities — •Ilias Samathrakis, Teng Long, Harish Kumar Singh, and Hongbin Zhang — Theory of Magnetic Materials, TU Darmstadt, Darmstadt, Germany

Topological transport properties in magnetic materials, such as the anomalous Hall conductivity (AHC) and anomalous Nernst conductivity (ANC), are promising for future spintronic applications, as they are dissipationless. In this work, we performed first-principles calculations to evaluate the AHC and ANC in 1827 ferromagnetic compounds. This is achieved by using an in-house developed high-throughput scheme to construct the Wannier functions automatically. Our results signify AHC values larger than 2000 S/cm in several ferromagnetic compounds and giant ANC which can be further tuned to realize heat rectification. Detailed analysis on the symmetry and the electronic structure is performed in order to understand the origin of such abnormal AHC and ANC.

MA 15: Computational Magnetism II

Time: Monday 15:00–16:30 Location: HSZ 403

MA 15.1 Mon 15:00 HSZ 403

Magnetic topological semimetals — •Maia G. Vergniory[1,2], Niels B. M. Schröter[3], Iñigo Robredo[1,5], Sebastian Klemenz[4], Robert Kirby[4], Vladimir Strocov[3], Jonas Krieger[3], Tianlun Yu[3], Fernando de Juan[1,2], Aitor Bergara[1,5], Jeniffer Cano[6], Barry Bradlyn[7], Andreas Schnyder[8], and Leslie Schoop[4] — [1]Donostia International Physics Center, 20018 Donostia-San Sebastian, Spain — [2]IKERBASQUE, Basque Foundation for Science, 48013 Bilbao, Basque Country, Spain. — [3]Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland — [4]Princeton University, Princeton NJ, USA — [5]Condensed Matter Physics Department, University of the Basque Country, Spain — [6]State University of New York at Stony Brook and Flatiron, USA — [7]University of Illinois at Urbana-Champaign, USA — [8]Max Planck Institute for Solid State Research, Stuttgart, Germany

Weyl fermions are expected to exhibit exotic physical properties such as the chiral anomaly, large negative magnetoresistance or Fermi arcs. Recently a new platform to realize these fermions has been introduced based on the appearance of a high-order nodal crossings at high symmetry points of certain space groups. In this talk will show we can also find these crossings in magnetic groups, such as the 3-fold and 6-fold magnetic degeneracies, which are topologically equivalent to spin-1 Weyl and Dirac fermions. We will conclude showing the experimental realization of some of these magnetic fermions in real materials. such as the non-symmoriphic CeSbTe or the topological properties of a metallic ferromagnetic pyrite.

MA 15.2 Mon 15:15 HSZ 403

Spin-polarized transport in anti-ferromagnetic RuO_2 — •Kyo-Hoon Ahn[1], Atsushi Hariki[1], Kwan-Woo Lee[2,3], and Jan Kuneš[1,4] — [1]Institute for Solid State Physics, TU Wien, 1040 Vienna, Austria — [2]Division of Display and Semiconductor Physics, Korea University, Sejong 30019, Korea — [3]Department of Applied Physics, Graduate School, Korea University, Sejong 30019, Korea — [4]Institute of Physics, Czech Academy of Sciences, Na Slovance 2, 182 21 Praha 8, Czechia

We will present the origin of antiferromagnetism (AFM) in RuO_2 using two approaches of static Hartree-Fock and density functional + dynamical mean-field theory. Since the ordering of two anti-parallel Ru sites does not change the translational symmetry, the AFM electronic structure is spin-polarized which is unique among commom antiferromagnets. In the Fermi surfaces the two spin channels are $\pi/2$-rotated to each other, classified as a spin-triplet d-wave Pomeranchuk instability. Comparing the energy difference of paramagnetic (PM) and AFM for the entire Brillouin zone (BZ), we found a hot spot at the point K2 on the PM Fermi surface, where nodal-lines meets the BZ edge as well as the Ru1 and Ru2 characters touch each other. By constructing a model Hamiltonian for the K2 point, we show that the nodal-lines close to the Fermi level are split by the applied staggered potential, and this is the origin of the AFM instability. [1] Ahn *et al.*, Phys. Rev. B **99**, 184432 (2019).

MA 15.3 Mon 15:30 HSZ 403

Optimal control of magnetization switching in nanowires — •Mohammad Badarneh[1], Grzegorz Kwiatkowski[1], and Pavel Bessarab[1,2,3] — [1]University of Iceland, Reykjavík, Iceland — [2]ITMO University, St. Petersburg, Russia — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

We explore theoretical limits for the energy-efficient control of switching phenomena in bistable magnetic nanowires. We calculate optimal control paths (OCPs) for the magnetization switching as functions of the switching time, damping and various parameters of the nanowires. Following an OCP involves concerted rotation of the magnetic moments in such a way that the system's internal modes are effectively used to aid magnetization switching. OCP calculations demonstrate that short nanowires reverse their magnetization via coherent rotation which can be induced by applying uniform external magnetic field with frequency defined by a collective in-phase precession of the magnetization. If the length of the wire exceeds a certain critical length, standing spin wave emerges during magnetization switching. Such spin wave assisted magnetization switching has recently attracted much attention as a promising technique to reduce the switching field for magnetic recording. Our results demonstrate that optimal switching mechanisms and corresponding control stimuli can be predicted from first principles, contributing to the development of low-power technologies.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138) and the Icelandic Reseach Fund (Grant No. 184949-052).

MA 15.4 Mon 15:45 HSZ 403

Magnetically controlled shapes of flexible ferromagnetic ribbons — •Kostiantyn V. Yershov[1,2], Volodymyr P. Kravchuk[2,3], Denis D. Sheka[4], and Jeroen van den Brink[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Taras Shevchenko National University of Kyiv, Ukraine

We consider flexible one- and two-dimensional ferromagnets with coupled magnetic and mechanical subsystems. The coupling between the magnetic and mechanical subsystems is driven by uniaxial anisotropy with the easy-axis normal or tangential to the magnetic film/ring and by the Dzyaloshinskii–Moriya interaction (DMI). We show that magnetic subsystem can determine the equilibrium shape of the ferromagnet. For elastic rings depending on the magnetic and elastic parameters and the size of the system one can obtain two different states: the onion state with the quasi-uniform magnetization and the vortex state with the magnetization oriented tangentially to the wire. We also show that the presence of DMI, results in a spontaneous deformation of a flexible magnetic ribbon. The final state of the ribbon is characterizing by the geometrical chirality whose sign is determined by the sign of the DMI constant. Depending on the mechanical, magnetic, and geometric parameters of the system one can obtain two different states: twisted-state with a straight central line and DNA-like state with a helix-shaped central line.

MA 15.5 Mon 16:00 HSZ 403

Meron/antimeron magnetic majority gates. — •Nikolaos Ntallis[1], Anders Bergman[1], Danny Thonig[3], Erik Sjöqvist[1], Anna Delin[2], Olle Eriksson[1,3], and Manuel Pereiro[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala 751 20, Sweden — [2]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, Electrum 229, SE-16440 Kista, Sweden — [3]Orebro University, SE-701 82, Orebro, Sweden

The development of electronic devices is undergoing the bottleneck of the performance and power consuming with continuous miniaturization. Spin based logic devices, which use the spin degree of freedom, have attracted a lot of research interest due to their potential in low-power operation, non-volatility and possibility to enable new computing applications. In this work, we present a model for a magnetic majority gate in which bits are assigned to merons/antimerons. We employ atomistic spin dynamics simulations via the UppASD package on nanostructures with symmetry of a kagome lattice. The merons can propagate along the edge of the material with negligible energy dissipation due to the presence of chiral edge modes. We demonstrate how different input modes can result into a single topological excitation in the output signal.

Funding Acknowledgment: This research is part of the project "Dynamic Phenomena of Magnetic Materials" funded by the Knut and

Alice Wallenberg Foundation.

MA 15.6 Mon 16:15 HSZ 403

Engineering relaxation pathways for plasmon-assisted nanomagnetic computation — •Naëmi Leo, Matteo Menniti, and Paolo Vavassori — CIC nanoGUNE, Donostia – San Sebastián, Spain

Nanomagnetic logic, which uses arrays of magnetostatically-coupled single-domain nanomagnets for computation, is a low-power alternative to current charge-based semiconductor devices. At the heart of the computation process lies the thermal relaxation from a magnetic-field-set moment configuration towards a low-energy state of the interacting ensemble. The computational functionality of such circuits is determined by the single-spin-flip connectivity of magnetic states, and the temperature-dependent rates for moment orientations, that regulate which relaxation pathways the system will explore.

Here we discuss recent developments to manipulate the relaxation kinetics of nanomagnetic circuits: As the spatial arrangement of the nanomagnets determines the configuration energies, pathways of different character – monotonic and intermittent – can be realised, which lend themselves to the implementation of deterministic and probabilistic computation, respectively. To allow for the kinetic control of relaxation pathways, plasmon-assisted photoheating of hybrid gold-magnet nanostructures allows for fast, spatially-, and sublattice-selective heating schemes within time scales as short as a few tens of picoseconds.

MA 16: INNOMAG e. V. Dissertation Prize

The Working Group Magnetism (Arbeitsgemeinschaft Magnetismus der DPG) awards a dissertation prize whose aim is to recognise outstanding research done within the framework of a doctorate and communication of this research in an excellent way, both verbally and in writing. The prize is kindly supported by INNOMAG e.V. In this finalists session, pre-selected nominees will present and defend their dissertation. Afterwards, the prize committee decides on the winner of the INNOMAG e.V. Dissertation Prize 2020 and the award of 1000 EURO.

Time: Monday 15:00–16:40 Location: POT 6

MA 16.1 Mon 15:00 POT 6

Spintronics with Terahertz Radiation: Probing and driving spins at highest frequencies — •Tom S. Seifert[1,2] and Tobias Kampfrath[2] — [1]ETH Zurich — [2]Free University Berlin

Spin-orbit interaction (SOI) will be of central importance for future spin-based electronics (spintronics) as it permits charge-to-spin conversion [1]. It is highly interesting to study spin dynamics at terahertz (THz) frequencies because spintronic devices should eventually operate at THz rates. In our experiments, we employ femtosecond optical and THz pulses to trigger ultrafast spin and charge dynamics in magnetic thin-film stacks with a strong SOI. We study THz emission from multilayers of magnetic and nonmagnetic materials [2,3]. By varying the magnet from conducting to insulating and from ferro- to antiferromagnetic, we aim at identifying different mechanisms generating ultrafast spin currents, including super-diffusive spin transport [4] and magnon-mediated transfer of spin angular momentum [5,6]. Finally, we drive spins at highest speeds by switching an antiferromagnetic CuMnAs memory element employing strong THz pulses [7]. These results were obtained in close collaborations with the research groups of J. Barker, C. Ciccarelli, T. Jungwirth, M. Kläui, Y. Mokrousov, M. Münzenberg, P.M. Oppeneer and D. Turchinovich. [1] A. Hoffmann et al., Phys. Rev. Appl. 4 (2015). [2] T. Kampfrath et al., Nat. Nanotech. 8 (2013). [3] T. Seifert et al., Nat. Phot. 10 (2016). [4] M. Battiato et al., PRL 105 (2010). [5] Kurebayashi et al., Nat. Mat. 10 (2011). [6] T. Seifert et al., Nat. Commun. 9 (2018). [7] K. Olejnik et al., Science Adv. 4 (2018).

MA 16.2 Mon 15:25 POT 6

Linear and nonlinear spin waves in nanoscale magnonic structures for data processing — •Qi Wang — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Spin waves, and their quanta magnons, attract attention as novel data carriers instead of electrons in future low-energy data processing units due to their short wavelength, low losses, and abundant nonlinear phenomena. Although separated spin-wave logic gates have already been demonstrated, the smallest sizes of these elements are in the ranges of a few micrometers and are not competitive with the current state-of-the-art CMOS technology. Moreover, the realization of an integrated magnonic circuit is still an unresolved challenge.

The objective of this talk is to present a nanoscale magnon directional coupler as a universal data processing unit for performing different logic operations and suitable for the integration into a magnonic circuit. First, the spin-wave characteristics in the nanoscale waveguides were studied theoretically and experimentally. This knowledge, as well as the numerical studies of the directional coupler, allowed for its realization at the nanoscale and the characterization using Brillouin Light Scattering spectroscopy. The nonlinear functionality of the coupler required for selective spin-wave guiding, depending on its amplitude, was demonstrated. Finally, the first integrated magnonic circuit consisting of two couplers and performing half-adder functionality was studied numerically. These studies were supported by ERC StG MagnonCircuits.

MA 16.3 Mon 15:50 POT 6

Highly efficient domain wall motion in ferrimagnetic bi-layer systems at the angular momentum compensation temperature — •Robin Bläsing and Stuart S. P. Parkin — Max Planck Institute of Microstructure Physics

Highly efficient current-induced motion of chiral domain walls was recently demonstrated in synthetic antiferromagnetic (SAF) structures due to an exchange coupling torque (ECT). The ECT derives from the antiferromagnetic exchange coupling through a ruthenium spacer layer between the two perpendicularly magnetized layers that comprise the SAF. In my dissertation I report that the same ECT mechanism applies to ferrimagnetic bi-layers formed from adjacent Co and Gd layers. In particular, I show that the ECT is maximized at the temperature T_A where the Co and Gd angular momenta balance each other, rather than at their magnetization compensation temperature T_M. Since the device temperature is significantly increased by the current pulses, taking into account Joule heating is of major importance when determining T_A. The velocity of the domain walls driven by electrical current is highly sensitive to longitudinal magnetic fields but I show that this is not the case near T_A. My studies provide new insight into the ECT mechanism for ferrimagnetic systems. Additionally, the minimum threshold current density to move domain walls is significantly decreased in Co/Gd bi-layers compared to SAF structures. The high efficiency resulting from the ECT and low threshold current density makes my study important for advanced domain wall-based spintronic devices.

MA 16.4 Mon 16:15 POT 6

Spin-orbit driven transport: Edelstein effect in Rashba systems and topological materials — •Annika Johansson — Institute of Physics, Martin Luther University Halle-Wittenberg, Halle, Germany

A charge current driven through a system with broken inversion symmetry can generate a spatially homogeneous spin polarization. This phenomenon is known as Edelstein effect [1,2]. Using semiclassical Boltzmann transport theory, I investigate the Edelstein effect in two- and three-dimensional Rashba systems and topological materials. Whereas the current-induced spin density in conventional isotropic Rashba systems is in-plane and perpendicular to the charge current, I show that the direction as well as the magnitude of the induced spin density can be strongly modified in systems with reduced symmetry, which provides new opportunities to control and manipulate the electrically induced magnetization [3].

Further, I predict a highly efficient Edelstein effect in three-dimensional Weyl semimetals, mainly originating from their topological surface states due to their favorable Fermi surface geometry, their strong spin polarization and the enhanced momentum relaxation time [4]. In comparison to Rashba systems, the Edelstein effect in Weyl semimetals is enhanced by at least one order of magnitude.

[1] A. Aronov and Y. Lyanda-Geller, JETP Lett. 50, 431 (1989).
[2] V. Edelstein, Solid State Commun. 73, 233 (1990).
[3] A. Johansson et al., Phys. Rev. B 93, 195440 (2016).
[4] A. Johansson et al., Phys. Rev. B 97, 085417 (2018).

MA 17: Skyrmions (jointly with MA, O) (joint session TT/MA)

Time: Monday 16:15–18:15 Location: HSZ 304

MA 17.1 Mon 16:15 HSZ 304

Quantum skyrmions in a triangular frustrated ferromagnet — •Vivek Lohani[1], Ciarán Hickey[1], Jan Masell[1,2], and Achim Rosch[1,3] — [1]Institute for Theoretical Physics, University of Cologne, Germany — [2]RIKEN Center for Emergent Matter Science, Japan — [3]Department of Physics, Harvard University, USA

Classically, skyrmions are described as tiny whirls of magnetization possessing a topological winding number. Their dynamics is similar to that of a charge, proportional to the winding number, that is coupled to an effective magnetic field. However, in the limit of small skyrmion size, quantum effects become important. Frustration stabilized skyrmion models – which exhibit degeneracy between classical skyrmions and antiskyrmions, and an additional zero mode, the *helicity* – provide a natural playground to study these quantum effects.

This begs the question – what is a quantum skyrmion? We argue that, in the quantum sector, a skyrmion is defined through the stable bound states of the Hamiltonian. By performing a numerical study, via exact diagonalization, we first demonstrate the existence of quantum skyrmions and identify the associated quantum selection rules. Furthermore, we explore their dynamics through a low energy, phenomenological Hamiltonian spanned by the translational and the helicity modes, wherein the coupling between translations and helicity leads to a rich dynamics. Most interestingly, we incorporate quantum tunneling, and how it breaks the degeneracy in the classical model and allows effective skyrmion charge to flip, thereby leading to a non-trivial bandstructure that is quite sensitive to the spin quantum number.

MA 17.2 Mon 16:30 HSZ 304

Quantum skyrmion state — •Evgeny A. Stepanov[1], Mikhail I. Katsnelson[2], and Vladimir V. Mazurenko[3] — [1]Institute of Theoretical Physics, University of Hamburg, Germany — [2]Radboud University, Institute for Molecules and Materials, Nijmegen, Netherlands — [3]Theoretical Physics and Applied Mathematics Department, Ural Federal University, Ekaterinburg, Russia

Skyrmions in physics of magnetism appear as classical spin structures that are formed in the systems as the result of a competition between different magnetic interactions. Such nontrivial magnetic textures can be observed in materials with the use of a spin-polarized scanning tunneling and Lorenz microscopy, or in X-ray and neutron scattering experiments. Theoretically, a skyrmion state can be described by solving a classical spin lattice problem or a corresponding continuous micromagnetic model. Here, we find that the classical skyrmion can be considered as a particular projection of a more general quantum skyrmion state. To perform a complete characterization of this novel state, we introduce a quantum analog for a classical skyrmion number that can be calculated as a scalar triple product of spin operators. We show that this quantity allows for a clear distinction of the quantum skyrmion state, which is characterized by a nontrivial correlation of spins in all three space directions, from other more simple spin orderings. On a basis of an exact numerical solution for supercells with up to 25 spins we demonstrate that the quantum skyrmion state can be obtained for a much broader range of magnetic fields than the corresponding classical skyrmion solution of the problem.

MA 17.3 Mon 16:45 HSZ 304

Vortex-Phase in Non-Centrosymetric Antiferromagnets — •Benjamin Wolba[1], Sebastian Mühlbauer[2], and Markus Garst[1] — [1]Institut für Theoretische Festkörperphysik (TFP), Karlsruhe Institut für Technologie (KIT), 76131 Karlsruhe — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, 85748 Garching, Germany

In this work we consider two-dimensional, non-centrosymmetric antiferromagnets, for which the competition between exchange and Dyzaloshinskii-Moriya interaction leads to the formation of spatially modulated phases of the staggered order parameter. Within the framework of Ginzburg-Landau theory we show that by applying a magnetic field parallel to the c-axis, which thus induces easy-plane anisotropy, one can stabilize a square lattice of vortices close to Neel temperature. Upon decreasing temperature, this vortex phase undergoes spontaneous symmetry breaking into a rectangular phase, which was not anticipated before. We discuss the relevance of our results for the chiral antiferromagnet $Ba_2CuGe_2O_7$.

MA 17.4 Mon 17:00 HSZ 304

Weak Crystallization of Fluctuating Skyrmion Textures in MnSi — Jonas Kindervater[1], Ioannis Stasinopoulos[1], Andreas Bauer[1], •Franz Xaver Haslbeck[1], Felix Rucker[1], Alfonso Chacon[1], Sebastian Mühlbauer[1], Christian Franz[1], Markus Garst[2,3], Dirk Grundler[1,4], and Christian Pfleiderer[1] — [1]TU München, Garching, Germany — [2]TU Dresden, Dresden, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

We report an experimental study of the emergence of nontrivial topological winding and long-range order across the paramagnetic to skyrmion lattice (SkL) transition in the transition metal helimagnet MnSi. Combining measurements of the susceptibility with small-angle neutron scattering, neutron-resonance spin-echo spectroscopy, and all-electrical microwave spectroscopy, we find evidence of skyrmion textures in the paramagnetic state exceeding 10^3 Å with lifetimes above several 10^{-9} s. Our experimental findings establish that the paramagnetic to SkL transition in MnSi is well described by the Landau soft-mode mechanism of weak crystallization, originally proposed in the context of the liquid-to-crystal transition. As a key aspect of this theoretical model, the modulation vectors of periodic small-amplitude components of the magnetization form triangles that add to zero. In excellent agreement with our experimental findings, these triangles of the modulation vectors entail the presence of the nontrivial topological winding of skyrmions already in the paramagnetic state of MnSi when approaching the SkL transition.

MA 17.5 Mon 17:15 HSZ 304

Tuning of the critical temperature of a superconducting thin film in proximity of a chiral magnet — •Julius Grefe, Marvin Sach, Bastian Rubrecht, Jannis Willwater, Stefan Süllow, and Dirk Menzel — Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

Theory has suggested a possibility to control the critical temperature T_C of a superconductor via the proximity effect with a magnetic system exhibiting a non-collinear spin structure [1]. MnSi being an archetype of the B20 structure shows helimagnetic behavior below $T_N = 29.5$ K and $B_{C1} = 100$ mT. The related pseudobinary compound $Fe_{1-x}Co_xSi$ with a tunable Néel-temperature from 0 K to 55 K even expands the accessible temperature range.

Superconducting Nb thin films have been deposited by molecular beam epitaxy on substrates prepared from Triarc-Czochralski grown single crystals. We investigate a shift of T_C in the Nb film upon reorientation of the spin helices in the substrate.

This proximity effect is suggested for usage in superconducting spin valves consisting only of a single magnetic layer and a thin superconducting film promising more simple and compact devices.

[1] N. G. Pugach et al., Appl. Phys. Lett. **111**, 162601 (2017).

MA 17.6 Mon 17:30 HSZ 304

Distribution of energy barriers associated with magnetic skyrmion decay in $Fe_{0.5}Co_{0.5}Si$ — •Alfonso Chacon[1], Marco Halder[1], Jonas Kindervater[1], Andreas Bauer[1], Sebastian Mühlbauer[2], Achim Rosch[3], and Christian Pfleiderer[1] —

[1]Physik Department, Technische Universität München, Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [3]Institut für Theoretische Physik, Universität zu Köln, Köln, Germany

We report comprehensive measurements of the magnetization and small-angle neutron scattering of the time-dependence of the decay of metastable skyrmion lattice order in $Fe_{0.5}Co_{0.5}Si$ after field cooling. Comparison of the SANS intensity pattern with the magnetization allows to identify contributions in the magnetization that are due to skyrmions only. Combining first-order reversal behaviour with the time dependence under carefully selected conditions, justifies the application of time versus temperature superposition and infer the distribution of energy barriers associated with the decay of magnetic skyrmions. The resulting distribution of energy barriers allows to discriminate between contributions due to the non-trivial topology and defect- and disorder-related pinning.

MA 17.7 Mon 17:45 HSZ 304

Helix reorientation at the transition between helical and conical phases of the chiral magnet Cu_2OSeO_3 — •Laura Köhler[1,4], Peter Milde[1], Erik Neuber[1], Philipp Ritzinger[1], Andreas Bauer[2], Christian Pfleiderer[2], Helmuth Berger[3], and Markus Garst[4] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]Technische Universität München, 85748 Garching, Germany — [3]École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [4]Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

In chiral magnets, the Dzyaloshinskii-Moriya interaction stabilizes a magnetic helix which is a one-dimensional periodic magnetic texture. The exact orientation of this helical texture is determined by the competition between crystalline anisotropies and the applied magnetic field. We study the reorientation process of the helix as a function of field in the insulating chiral magnet Cu_2OSeO_3 using magnetic force microscopy. As a function of field, we determine the wavelength projected onto the sample surface as well as the electric polarization induced by the magnetoelectric coupling. Our experimental observations are well described by an effective Landau theory for the helix orientation as previously applied to MnSi [1].

[1] A. Bauer, A. Chacon, M. Wagner, M. Halder, R. Georgii, A. Rosch, C. Pfleiderer, M. Garst, PR B 95, 024429 (2017).

MA 17.8 Mon 18:00 HSZ 304

Skyrmion Lattice Magnet Gd_2PdSi_3 Studied by High-Resolution Dilatometry — •Sven Spachmann[1], Matthias Frontzek[2], Chongde Cao[3], Wolfgang Löser[4], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Oak Ridge National Laboratory, Oak Ridge, USA — [3]Northwestern Polytechnical University, Xi'an, China — [4]Leibniz Institute for Solid State and Materials Research (IFW), Dresden, Germany

A Bloch-type skyrmion state emerging in low magnetic fields has recently been reported for the frustrated centrosymmetric triangular-lattice magnet Gd_2PdSi_3 [1]. Here, we present high-resolution thermal expansion and magnetostriction measurements on single crystals of this material in order to study the phase diagram and in particular the transitions to the skyrmion phase. In zero magnetic field, a single peak in the thermal expansion coefficient indicates the onset of long-range antiferromagnetic order at $T_N = 19.7$ K, which exhibits uniaxial pressure dependencies of opposite sign along the a- and c-axis, respectively. Up to $B = 4$ T, four known phases are confirmed, including the skyrmion phase for $B||c$ which appears in a discontinuous transition. In addition, a previously non-reported phase is observed. The anomalies in thermal expansion and magnetostriction at the different phase boundaries as well as the respective uniaxial pressure dependencies imply significant changes in the spin-lattice coupling for different fields.

[1] T. Kurumaji et al., Science 10.1126/science.aau0968 (2019)

MA 18: Magnetic Particles and Clusters

Time: Monday 16:45–18:45 Location: HSZ 403

MA 18.1 Mon 16:45 HSZ 403

Shape controlled synthesis of magnetite nanoparticles — •Ilona Wimmer[1], Bastian Welte[2], Sebastian Polarz[2], and Mikhail Fonin[1] — [1]Department of Physics, University Konstanz, D-78457 Konstanz — [2]Department of Chemistry, University Konstanz, D-78457 Konstanz

Magnetic nanoparticles show a variety of unique properties such as superparamagnetism, magnetic single domain states, enhanced magnetic moments and magnetic anisotropies. These phenomena are not found in their bulk counterparts and make magnetic nanoparticles highly interesting for many applications ranging from medicine to data storage.

Here we report the synthesis of magnetite (Fe_3O_4) nanoparticles of different shapes, like spheres, hexagons and rods. The particles' crystallographic structure was characterized by means of x-ray diffraction and transmission electron microscopy confirming the phase purity and providing information about particles' shape and size. The rod-like particle shape exhibits a broad size distribution. Therefore, a special centrifugation protocol was introduced and several assembly techniques like drying-mediated self-assembly or external field directed self-assembly were used to achieve the ordered assembly of the particles. Further, we performed magnetic measurements revealing a superparamagnetic behavior with a blocking temperature of 145 K.

MA 18.2 Mon 17:00 HSZ 403

Tuning the structural and magnetic properties of transition metal oxide nanoparticles — •Xiao Sun[1,2], Ann-Christin Dippel[1], Aladin Ullrich[3], Oleg Petracic[2], and Thomas Brückel[2] — [1]Deutsches Elektronen-Synchrotron DESY, Photon Science, Hamburg, Germany — [2]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]Lehrstuhl für Experimentalphysik II, Universität Augsburg, Augsburg, Germany

Magnetic nanoparticles (NPs) have attracted interests in both fundamental research and industry. We focus on two transition metal oxide systems: manganese oxide and iron oxide. The structural information of the particles was characterized using X-ray powder diffraction, total scattering experiments with pair distribution function analysis, small angle scattering as well as scanning electron microscopy. The magnetic properties were studied using a SQUID magnetometer. In the hysteresis loops of the as-prepared NPs an exchange bias effect is found. By comparing hysteresis loops cooled at different magnetic fields, a hardening effect is observed, i.e. the squareness and hardness of hysteresis loops is significantly enhanced with increasing magnetic cooling field. By varying the oxygen content inside the NPs via different annealing procedures, their crystallographic structures change. The bonding lengths as well as the correlation lengths of different phases in the particles are obtained using total scattering with pair distribution function analysis. The relationship between the correlation lengths and the exchange bias as well as the magnetic hardening effects is elucidated.

MA 18.3 Mon 17:15 HSZ 403

Unravelling the Nucleation, Growth, and Faceting of Magnetite-Gold Nanohybrids — Yulia A. Nalench[1], Igor V. Shchetinin[1], Alexander S. Skorikov[2], Pavel S. Mogilnikov[1], Michael Farle[3], Alexander G. Savchenko[1], Alexander G. Majouga[1,2,4], Maxim A. Abakumov[1,5], and •Ulf Wiedwald[1,3] — [1]National University of Science and Technology MISIS, Moscow, Russia — [2]Lomonosov Moscow State University, Russia — [3]Faculty of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Germany — [4]D. Mendeleev University of Chemical Technology of Russia, Moscow, Russia — [5]Department of Medical Nanobiotechnology, Russian National Research Medical University, Moscow, Russia

We study the nucleation and growth processes of $Fe_3O_4 - Au$ hybrid NPs in detail by taking probes of the reaction mixture during synthesis and analysis using laboratory equipment (TEM, XRD, and magnetometry) for typically 10 μL samples. From the three independent experiments we extract the NP size at 12 stages of the synthesis showing identical trends and good quantitative agreement. Two independent processes occur during synthesis of $Fe_3O_4 - Au$ NPs, the nucleation and growth of spherical Fe_3O_4 NPs on the surface of Au seeds during the heating stage and their faceting towards octahedral shape during reflux. Stopping the reaction at a certain point allows to adjust the NP size and shape improving e.g. their capabilities in biomedical applications.

MA 18.4 Mon 17:30 HSZ 403

Element-specific characterization of catalytic ferrite nanoparticles via Mössbauer spectroscopy — •Soma Salamon[1], Joachim Landers[1], Georg Bendt[2], Swen Zerebecki[3], Sascha Saddeler[2], Anna Rabe[2], Malte Behrens[2], Stephan Schulz[2], Stephan Barcikowski[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Institute of Inorganic Chemistry and CENIDE, University of Duisburg-Essen — [3]Institute of Technical Chemistry I and CENIDE, University of Duisburg-Essen

Mössbauer spectroscopy is utilized as an element-specific, non-destructive measurement method to probe hyperfine interactions in ferrite materials, which are promising candidates for electrocatalysis applications. Evaluation of low temperature spectra recorded at high magnetic fields allows us to determine the degree of inversion in spinel systems, providing important clues on the distribution of Fe-ions on different crystallographic sites, while the isomer shift makes it possible to draw conclusions on the valency states. This enables us to correlate changes in ion distribution in the lattice with improvements in catalytic activity, which can be achieved by a number of methods. Several examples on nanoparticulate systems will be shown: The modification of particle composition during and after synthesis, as well as a laser-treatment of nanoparticles. In all cases, our measurement method offers valuable insights into which parameters are modified by the respective sample treatment, facilitating a more effective search for the best method to increase catalytic efficiency. Funding by the DFG via the CRC/TRR 247 (Project B2) is gratefully acknowledged.

MA 18.5 Mon 17:45 HSZ 403

Electronic Properties of Stable Pi-Radicals Grown on Metal Substrates — •Radovan Vranik, Vitalii Stetsovych, Simon Feigl und Stefan Müllegger — Institut für Halbleiter- und Festkörperphysik, Johannes Kepler Universität, Linz, Österreich

Stabile organische Radikale erregen seit der Entdeckung von Triphenylmethyl bei Moses Gomberg (1900) dank ihrer interessanten paramagnetischen Eigenschaften die Aufmerksamkeit der Physiker. Ihre magnetische Eigenschaften wurden mittels Bulk-Methoden wie Elektronenspinresonanz (ESR) ausgiebig erforscht. Seit einiger Zeit werden immer mehr stabile organische Radikale untersucht, die auf einem Substrat adsorbiert werden. Es sind insbesondere Methoden wie Rastertunnelmikroskopie (STM) und *spektroskopie (STS), die die Untersuchung der elektronischen und magnetischen Eigenschaften von einzelnen Molekülen ermöglichen, inklusive einzelnen isolierten Radikalen und molekularen Clustern. In diesem Beitrag berichte ich von den Ergebnissen unserer letzten STM- und STS-Messungen von zwei stabilen Pi-Radikalen, adsorbiert bei Raumtemperatur auf Oberflächen von Ag(111) und Au(111) Einzelkristallen, nämlich Bisdiphenylene-phenylallyl (BDPA, auch als Kölsch Radikal bekannt) und 2,2-Diphenyl-1-picrylhydrazyl (DPPH). Ich werde insbesondere auf die Unterschiede von den elektronischen und geometrischen Eigenschaften dieser zwei Radikale eingehen, die mittels STM- und STS-Messungen bei der Temperatur von 5 K an einzelnen Molekülen und an ganzen Clustern untersucht wurden. Die erforschten Cluster entstanden durch Selbstausrichtung von Einzelmolekülen bei Raumtemperatur.

MA 18.6 Mon 18:00 HSZ 403

Beyond SPIONs in enhanced magnetic fluid hyperthermia — •Yevhen Ablets, Imants Dirba, and Oliver Gutfleisch — Technical University of Darmstadt, Darmstadt, Germany

Magnetic fluid hyperthermia (MFH) using magnetic nanoparticles that produce heat in response to an external alternating magnetic field offers a promising therapy in cancer treatment. Typically, superparamagnetic iron oxide nanoparticles (SPIONs), e.g., *-Fe2O3 or Fe3O4 are used, as they are inexpensive to produce, chemically stable and biocompatible. However, due to their ferrimagnetic nature the saturation magnetization remains moderate which limits the dissipated heat power when exposed to an AC magnetic field. In this work therefore, we study alternative Fe-based materials synthesized by thermal decomposition of iron pentacarbonyl in different gaseous atmospheres. The resultant nanoparticles show higher compared to iron oxides and deliver enhanced heating power. The MFH heating performance is correlated with the measured particle morphology (TEM), crystal structure (SAED) and magnetic properties (VSM).

MA 18.7 Mon 18:15 HSZ 403

Multidimensional actuation of microparticles with unique magnetic and biological functionalizations — •Meike Reginka, Andreea Tomita, Rico Huhnstock, Dennis Holzinger, and Arno Ehresmann — Institute of Physics and CINSaT, University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

In this work we present a transportation concept for magnetic particles based on the stray field design of exchange-biased micromagnetic arrays. Besides the one-dimensional transport of particle rows, a two-dimensional motion of particles above checker-board patterned substrates and their three-dimensional movement through stripe patterned tubes were realized. Extending the variety of magnetic probes starting from superparamagnetic particles (SPPs), we furthermore investigated the applicability of the transportation mechanism for differently functionalized microparticles. SPPs with biochemically coupled proteins were transported, concluding that the proteins' specific requirements towards the liquid influence but do not inhibit the directed motion. Besides, we magnetically designed particles with anisotropic properties: Janus particles (JPs) result from the deposition of a magnetic film on top of non-magnetic microspheres or lithographically structured particles of arbitrary shape. The JPs' degrees of motion can be selectively addressed by magnetic fields offering control not only over their position but also over their orientation. Synchronized rotational dynamics of the JPs induced by rotating magnetic fields were revealed along with the directed transport in the above described magnetic stray field landscapes.

MA 18.8 Mon 18:30 HSZ 403

Testing energy landscapes with trapped magnetic beads — •Moritz Quincke, Florian Ostermaier, Isiaka Lukman, Benjamin Riedmüller, and Ulrich Herr — Institut für Funktionelle Nanosysteme, Ulm, Germany

Optical tweezers have been established as a powerful tool for passive microrheology of living cells and single molecule stretching. Magnetic tweezers offer a similar range of achievable force and particle localization, but may also be used in strongly absorbing environment. In addition, perspective Lab-on-Chip applications may benefit from the lack of requirement of high power Laser light. We have already demonstrated successful trapping of single commercially available magnetic beads using a combination of the field gradient produced by a micro structured ring conductor and a superimposed homogeneous magnetic field.

Here we present studies of two magnetic beads simultaneously trapped in the same ring structure which are coupled via magnetic dipole-dipole interaction. From the dynamics of the motion of the coupled beads in the trap potential, we extract information about the magnetic energy landscape formed by the combination of trap field and bead magnetization.

We use an approach based on probability distribution of particle position inside a potential energy landscape model. The model parameters extracted in this way are compared to results obtained by direct evaluation of the particle trajectories.

MA 19: Characterization and Instrumentation

Time: Monday 17:15–19:00 Location: HSZ 101

MA 19.1 Mon 17:15 HSZ 101

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

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

MA 19.2 Mon 17:30 HSZ 101

Optimally Controlled Pulses on NV Centers — •Thomas Reisser[1,3], Marco Rossignolo[2,4], Ressa S. Said[2], Tommaso Calarco[1,3], Simone Montangero[4], and Fedor Jelezko[2] — [1]Institute for Quantum Control, PGI-8, Forschungszentrum Jülich GmbH, Jülich — [2]Institute for Quantum Optics, Ulm University, Ulm — [3]Institute for Theoretical Physics, University of Cologne, Cologne — [4]Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Padova

Nitrogen vacancy centers in diamond display remarkable features such as optical polarizability and the read-out of their state at room temperature. Sensitivity to temperature and electric and magnetic fields enables their application for quantum sensing. Unexpected noise sources and long-term drifts of the driving magnetic field strength affect its interaction with the qubit. Long pulse schemes for quantum state preparation are not always suitable due to limited lifetimes. Hence, we designed optimally controlled pulses to drive the nitrogen vacancy center to a target state with robustness against frequency detuning within the transfer time of a standard square pulse. This can be achieved by a time-dependent variation of the applied pulse amplitude. Simulations showed further improvement in robustness for simultaneous carrier frequency modulation. As a next step, closed-loop optimization could be performed, where the simulated model is replaced by direct measurements on the NV center in the laboratory. Therefore, the remote dressed chopped random basis algorithm software (RedCRAB) is included in Qudi, a software suite for experiment control.

MA 19.3 Mon 17:45 HSZ 101

Optical magnetometer based on NV centers in diamond for calibration of superconducting vector magnets — •Severine Diziain[1], Nicole Raatz[2], Sebastien Pezzagna[2], Robert Staacke[2], Roger John[2], Lukas Botsch[1], Bernd Abel[3], Jan Meijer[2], and Pablo Esquinazi[1] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, SUM, Leipzig, Germany — [2]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, AQS, Leipzig, Germany — [3]Leibniz-Institut für Oberflächenmodifizierung e. V., Leipzig, Germany

Due to their ability to generate highly stable fields, superconducting vector magnets are commonly used for the characterization of magnetic properties of materials developed for spintronic applications. Because of flux trapping, the magnitude of the generated magnetic fields depends on the previous magnetization of the magnet and can not be determined by the applied current but must be measured. Usually vectorial magnetic field measurements are performed with three Hall sensors that have to be calibrated at all temperatures since their Hall voltage and offset are temperature dependent. This calibration can not be easily done inside a magnet that has been already energized because of remanent fields. Here we present an alternative that consists in measuring vectorial magnetic fields with a single optical magnetometer based on NV centers in diamond. These magnetometers allow for an easy reset of the vector magnet and therefore can be calibrated in-situ. Additionally since a single detector is enough to measure a vectorial field instead of three Hall sensors a better accuracy is obtained.

MA 19.4 Mon 18:00 HSZ 101

Scanning thermal gradient microscopy as a tool to read and write domains in non-collinear antiferromagnets — •Helena Reichlova[1], Tomas Janda[2], Joao Godinho[3], Anastasios Markou[4], Dominik Kriegner[4], Richard Schlitz[1], Jakub Zelezny[3], Zbynek Soban[3], Mauricio Bejarano[5], Helmut Schultheiss[5], Petr Nemec[2], Tomas Jungwirth[3], Claudia Felser[1], Joerg Wunderlich[3], and Sebastian T.B. Goennenwein[1] — [1]Institut für Festkörper- und Materialphysik and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden — [2]Faculty of Mathematics and Physics, Charles University in Prague — [3]Institute of Physics, Academy of Science of the Czech Republic — [4]Max Planck Institute for Chemical Physics of Solids — [5]Institute of Ion Beam Physics and Materials Research, HZDR

We present scanning thermal gradient microscopy as a tool to visualize magnetic structure in a non-collinear antiferromagnet Mn_3Sn thin films [1]. The technique is based on a laser induced thermal gradient which is scanned over the sample surface. The out-of-plane thermal gradient generates an in-plane thermo-voltage via the anomalous Nernst effect, which depends on the domain orientation and therefore yields magnetic spatial contrast. We further show that a domain pattern can be modified via heat assisted writing. Our work opens a route not only to image domains in non-collinear antiferromagnets but also to prepare well-defined domain configurations. [1] Reichlova, et al., Nat. Comm. 10, 5459 (2019)

MA 19.5 Mon 18:15 HSZ 101

High-field thermal expansion and magnetostriction at the High Field Magnet Laboratory (HFML-EMFL) — •Steffen Wiedmann[1], Masoumeh Keshavarz[2], Lisa Rossi[1], Ben Bryant[1], and Robert Kuechler[3] — [1]Field Magnet Laboratory (HFML-EMFL), IMM, Radboud University, Nijmegen, the Netherlands — [2]Molecular Imaging and Photonics, Department of Chemistry, KU Leuven, Leuven, Belgium — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Thermal expansion and magnetostriction experiments are an important and very sensitive tool for the investigation of phase transitions in condensed matter. At the high Field Magnet Laboratory (HFML) in Nijmegen, capacitive dilatometry that allows to measure both quantities in magnetic fields up to 38 T and down to 0.3 K has been developed with a resolution down to 0.1 nm at highest magnetic fields [1].

We present the current setups at the HFML and show recent results of dilatometry experiments such as (i) thermal expansion in lead halide perovskite materials to identify their phase transitions temperatures down to 4.2 K [2] and (ii) negative thermal expansion in the high-field, half-magnetization plateau phase of the frustrated magnetic insulator CdCr2O4 [3].

An outlook for further technical development will also be given.

[1] R. Kuechler et al., Review of Scientific Instruments 88 (2017), 083903. [2] M. Keshavarz et al., Advanced Materials 31 (2019), 1900521. [3] L. Rossi et al., Physical Review Letters 123 (2019), 027205.

MA 19.6 Mon 18:30 HSZ 101

Looking deeper into matter and magnets - scalable recognition of inhomogeneities in video data — Illia Horenko[1], •Davi Rodrigues[2], Terence O'Kane[3], and Karin Everschor-Sitte[2] — [1]Universita della Svizzera Italiana, Faculty of Informatics, Via G. Buffi 13, TI-6900 Lugano, Switzerland — [2]Johannes-Gutenberg University of Mainz, Faculty of Physics, Staudinger Weg 9, 55128 Mainz, Germany — [3]Climate Forecasting, CSIRO Oceans and Atmosphere, Castray Esplanade, 7001 Hobart, Tasmania

We present two physics motivated tools which enhances significantly the data extraction from time-discretized measurement data, i.e. video data, compared to state-of-the-art computational methods. We show that these measures detect very subtle material inhomogeneities from magnetic imaging measurements - down to 1% difference in material parameters. We demonstrate the working principle of these measures based on the 2d inhomogeneous Ising model, micromagnetic simulation data as well as experimental magnetization dynamics imaging data.

More generally, we show that these measures - the latent temperature and the latent entropy - reveal information about the system's memory and its stochasticity, respectively, and they are applicable on a broad range of fields including biology and climate research. Furthermore we prove that they outperform common statistical and machine learning instruments as the iteration costs (scaling and memory requirements) of the algorithm to compute these measures are independent of the data statistics size.

MA 19.7 Mon 18:45 HSZ 101

First Operational Experience and Characterization of a Superconducting Transverse Gradient Undulator for Compact Laser Wakefield Accelerator-Driven FELs — •Kantaphon Damminsek[1], Axel Bernhard[1], Julian Gethman[1], Maisui Ning[1], Anke-Susanne Müller[1], Sebastian Richter[2], Robert Rossmanith[3], Farzad Jafarinia[3], Florian Burkart[3], and Malte Kaluza[4] — [1]Karlsruhe Institute of Technology — [2]CERN — [3]DESY, Hamburg — [4]Helmholtz Institute Jena

A 40-period superconducting transverse gradient undulator (TGU) has been designed and fabricated at Karlsruhe Institute of Technology (KIT). Combining a TGU with a Laser Wakefield Accelerator

(LWFA) is a potential key for realizing an extremely compact Free Electron Lasers (FELs) radiation source: LWFAs have an unprecedentedly high longitudinal electric field inside the laser-driven plasma wave; the TGU scheme is a viable option to compensate the challenging properties of the LWFA electron beam in terms of beam divergence and energy spread. In this contribution, we report on the operational experience of this TGU inside its own cryostat and show first results of the characterization measurement and the further plan for experiments at the SINBAD Facility (DESY, Hamburg) and the JETI200 Laser laboratory in Jena.

MA 20: PhD Focus Session: Symposium on "Strange Bedfellows – Magnetism Meets Superconductivity" (joint session MA/AKjDPG)

At first sight, it seems that the phenomena of magnetism and superconductivity do not go along, as indicated by the Meissner effect, when a magnetic field is completely expelled from the interior of a conventional superconductor. However, the synergy of these two manifestations of nature in condensed matter does occur and can be rather interesting! Theoretical works have predicted the existence of exotic states at the interface between a superconductor and a magnet, such as the sought-after Majorana fermions and spin-triplet superconductivity. The first have been predicted to route an efficient way to implement quantum computers (currently a European scientific flagship), while the latter allows the creation of spin-polarized supercurrents, opening up fundamentally new possibilities for spintronics. Therefore, our symposium aims at putting together experts to provide a fundamental and practical understanding of the subject to discuss most recent developments from the theoretical and experimental sides, and to show perspectives for applications.

Organizers: Flaviano José dos Santos, Markus Hoffmann, Annika Stellhorn – (Forschungszentrum Jülich and Peter Grünberg Institut)

Time: Tuesday 9:30–13:00 Location: HSZ 04

Invited Talk MA 20.1 Tue 9:30 HSZ 04
Magnetism and superconductivity: building new physics one atom at a time — •Alexander Balatsky — Nordita and University of Connecticut

In this tutorial I will review the effects of magnetism and electronic defect in conventional and unconventional superconductors. The extreme case of quantum engineering where one builds magnetic and electronic features one atom at a time has proved to be a versatile approach. Impurities and defects are pair breakers in superconductors. I will discuss how defects can also enable new features in superconductors like intragap resonances, topological Majorana modes and seed new superconducting phases. Looking forward I will discuss how we might induce novel physics in superconductors with precise quantum impurity band engineering.

MA 20.2 Tue 10:15 HSZ 04
Magnetic Impurities and Anisotropic Multiband Superconductors — •Tom Saunderson[1], Gábor Csire[3], James Annett[1], Balázs Úfalussy[2], and Martin Gradhand[1] — [1]HH Wills Laboratory, University of Bristol, UK — [2]Wigner Research Centre for Physics, PO Box 49, H-1525 Budapest, Hungary — [3]Catalan Institute of Nanoscience and Nanotechnology (ICN2), Barcelona, Spain

Scanning tunnelling microscopy for superconductors has seen a flourish of activity in the last few years. It has become a powerful tool for determining the underlying fundamental properties of the gap structures in unconventional superconductors within the presence of impurities [1]. It has also been interesting to observe the pair-breaking effects that magnetic impurities have in conventional superconductors which lead to bound states [2]. Such states are even a possible source of Majorana Fermions [3]. We present the implementation of the Bogoliubov-de Gennes (BdG) equation into a Green‘s function (KKR) first principles method [4]. This method combines the full complexity of the underlying electronic structure and Fermi surface geometry with a simple phenomenological parametrisation for the superconductivity, whilst also being ideal to model impurities and interfaces. We present various test cases of simple superconductors in the presence of magnetic impurities, and assess the orbital character of the ensuing bound states.

[1] Ø. Fischer *et al*, Rev. Mod. Phys., **79**, 353 (2007)
[2] B. W. Heinrich *et al*, Prog. Surf. Sci., **93**, 1 (2018)
[3] S. Nadj-Perge *et al*, Science, **346**, 1259327 (2014)
[4] T. G. Saunderson *et al*, arXiv:1911.04163

Invited Talk MA 20.3 Tue 10:30 HSZ 04
Yu-Shiba-Rusinov states of single magnetic atoms and nanostructures probed by scanning tunneling spectroscopy — Eva Liebhaber[1], Michael Ruby[1], Benjamin W. Heinrich[1], Gaël Reecht[1], Kai Rossnagel[2,3], Felix von Oppen[1,4], and •Katharina J. Franke[1] — [1]Freie Universität Berlin, Berlin, Germany — [2]Christian-Albrechts-Universität Kiel, Kiel, Germany — [3]Deutsches Elektronen Synchrotron, Hamburg, Germany — [4]Dahlem Center for Complex Quantum Systems, Berlin, Germany

The exchange coupling of individual magnetic atoms with the Cooper pairs of a superconducting substrate leads to Yu-Shiba-Rusinov (YSR) bound states inside the superconducting energy gap. Their bound state energy and spatial extent can be probed by scanning tunneling spectroscopy [1-4]. Chains of magnetic adatoms have attracted particularly strong attention due to the formation of Majorana bound states at their terminations [5].

Here, we investigate individual magnetic atoms on Pb and $2H$-$NbSe_2$ substrates. We observe intriguing patterns of YSR states around the adatoms, which are determined by the adatom's d-levels as well as local symmetries of the adsorption potential. When the adatoms are sufficiently close, the YSR states hybridize, eventually giving rise to YSR bands in atomic chains.

[1] Yazdani *et al.*, Science 275, 1767 (1997); [2] Ji *et al.*, Phys. Rev. Lett. 100, 226801 (2008); [3] Franke *et al.*, Science 332, 940 (2011); [4] Ménard *et al.*, Nature Phys. 11, 1013 (2015); [5] Nadj-Perge *et al.*, Science 346, 602 (2014).

MA 20.4 Tue 11:00 HSZ 04
Symmetric and antisymmetric combinations of Yu-Shiba-Rusinov states in antiferromagnetic dimers — •Philip Beck, Lucas Schneider, Levente Rósza, Jens Wiebe, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstraße 9-11, 20355 Hamburg

Magnetic atoms coupled to the Cooper pairs of a superconductor give rise to excitations in the superconductor's energy gap, so-called Yu-Shiba-Rusinov (YSR) states [1]. Theoretical proposals and experimental results have shown that, for ferromagnetically coupled atoms, the in-gap states hybridize and form symmetric and antisymmetric linear combinations.[2-4]

In our scanning tunneling spectroscopy study we reveal the evolution from multi-orbital YSR states of single transition metal atoms placed on an elemental superconductor to the YSR states of artificially constructed dimers with different interatomic separations and orientations. Even though the coupling in particular dimers, as calculated by DFT, is antiferromagnetic, we still observe a splitting of some of their orbital YSR states into symmetric and antisymmetric combinations. This unexpected behavior will be discussed and explained by advanced theoretical models.

We acknowledge funding by the ERC via the Advanced Grant ADMIRE (no. 786020) and by the SFB925 of the DFG.

[1] A. Rusinov, JETP **9**, 85 (1969). [2] D. K. Morr *et al.* PRB **67**, 020502 (2003). [3] M. Ruby *et al.* PRL **120**, 156803 (2018). [4] D.-J. Choi *et al.* PRL **120**, 167001 (2018).

Invited Talk MA 20.5 Tue 11:15 HSZ 04

Majorana bound states in magnetic skyrmions — •Jelena Klinovaja — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Magnetic skyrmions are highly mobile nanoscale topological spin textures. A magnetic skyrmion of an even azimuthal winding number placed in proximity to an s-wave superconductor hosts a zero-energy Majorana bound state in its core, when the exchange coupling between the itinerant electrons and the skyrmion is strong [1]. This Majorana bound state is stabilized by the presence of a spin-orbit interaction. We propose the use of a superconducting tri-junction to realize non-Abelian statistics of such Majorana bound states.

Antiferromagnetic skyrmion crystals are magnetic phases predicted to exist in antiferromagnets with Dzyaloshinskii-Moriya interactions. Their spatially periodic noncollinear magnetic texture gives rise to topological bulk magnon bands characterized by nonzero Chern numbers [2,3]. We find topologically-protected chiral magnonic edge states over a wide range of magnetic fields and Dzyaloshinskii-Moriya interaction values. Edge states appear at the lowest possible energies, namely, within the first bulk magnon gap. Thus, antiferromagnetic skyrmion crystals show great promise as novel platforms for topological magnonics.

[1] G. Yang, P. Stano, J. Klinovaja, and D. Loss, Phys. Rev. B 93, 224505 (2016). [2] S. Diaz, J. Klinovaja, and D. Loss, Phys. Rev. Lett. 122, 187203 (2019). [3] S. Diaz, T. Hirosawa, J. Klinovaja, and D. Loss, arXiv:1910.05214.

MA 20.6 Tue 11:45 HSZ 04

Interplay of Shiba and Majorana states in nanostructures deposited on superconducting surfaces — •Uriel A. Aceves-Rodriguez, Filipe S. M. Guimarães, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Majorana Bound States (MBS) are zero-energy modes that have become one of the leading candidates for the next generation of qubits, due to their topological protection and exchange statistics [1]. In pursuance of handling these entities, we implemented a multi-orbital tight-binding scheme, offering a realistic description of the electronic structure, to solve the Bogoliubov-de Gennes equations self-consistently. We investigate in-gap states, such as Shiba states, emerging from various nanostructures on typical superconducting substrates. Additionally, we examine the occurrence of MBS at superconducting/non-superconducting interfaces of nanowires deposited on superconducting surfaces.

This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).

[1] J. Alicea, Rep. Prog. Phys. 75 (2012) 076501

Invited Talk MA 20.7 Tue 12:00 HSZ 04

Orbital selective superconductivity in iron-based superconductors — •Pengcheng Dai — Rice University

Superconductivity in iron-based superconductors emerges from long-range ordered antiferromagnetic phase with nematic order that breaks four-fold rotational symmetry of the underlying lattice. In spite of considerable work over the past decade, much is unclear concerning the microscopic origin of superconductivity and its relationship with magnetism, nematicity, and orbital order. In this talk, I will summarize our recent inelastic neutron scattering studies of iron-based superconductors, focusing on studying the relationship between magnetism, nematic order, and superconductivity. We find that orbital selective magnetic excitations and superconductivity are central to a microscopic understanding of these materials.

MA 20.8 Tue 12:30 HSZ 04

Inductive detection of field- and damping-like inverse spin-orbit torques in superconductor/ferromagnet heterostructures — •Manuel Müller[1,2], Lukas Liensberger[1,2], Luis Flacke[1,2], Hans Huebl[1,2,3], Akashdeep Kamra[4], Wolfgang Belzig[5], Rudolf Gross[1,2,3], Mathias Weiler[1,2], and Matthias Althammer[1,2] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [4]Norwegian University of Science and Technology, Trondheim, Norway — [5]Fachbereich Physik, Universität Konstanz, Konstanz, Germany

Proximity effects at superconductor(SC)/ferromagnet(FM) interfaces provide novel functionality in the field of superconducting spintronics. We present experiments, where we probe the angular momentum transport across the SC/FM interface using a phase resolve broadband ferromagnetic resonance (bbFMR) technique that allows to measure both field- and damping-like inverse spin orbit torques (iSOT)[1]. We extend this iSOT analysis to make it applicable for SC/FM-bilayers and study iSOTs in a series of multilayers based on $NbN/Ni_{80}Fe_{20}$ as a function of temperature. We observe distinct changes in damping-like and field-like iSOT at the superconducting transition temperature T_c. Our findings reveal symmetry and strength of iSOTs at the SC/FM interface and provide guidance for future superconducting spintronics devices. [1] A. Berger. Phys. Rev. B. **97**: 94407. (2018).

MA 20.9 Tue 12:45 HSZ 04

Electronic and magnetic character of UTe_2 unconventional superconductor — Alexander B. Shick[1] and •Warren E. Pickett[2] — [1]Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Physics, University of California-Davis, Davis, California, USA

The interplay between ferromagnetism and superconductivity is a challenging problem in the coupling between the two major states of condensed matter. We report density functional theory plus Hubbard U calculations for recently discovered the orthorhombic uranium dichalcogenide superconductor [1]. The UTe_2 displays superconductivity below 1.7 K, with the anomalous feature that the specific heat coefficient does not vanish at zero temperature limit, but rather weakly diverges, suggesting very low energy ungapped quantum fluctuations. The analysis of the experimental data indicates that this actinide compound is a nearly ferromagnetic spin-triplet superconductor. The DFT+U calculations for ferromagnetic alignment [2] reveal that the states are dominated by the j=5/2 configuration, with the $j_z = \pm 1/2$ sectors being effectively degenerate and half-filled. The Fermi surfaces are large and strongly metallic, and display low-dimensional features, reminiscent of the ferromagnetic superconductor UGe_2. Our calculations can provide a platform for modeling unusual behavior of UTe_2. [1] S. Ran et al., Science 365, 684 (2019); [2] A. B. Shick, and W. E. Pickett, PRB 100, 134502 (2019).

MA 21: Ultrafast Magnetization II

Time: Tuesday 9:30–13:15 Location: HSZ 101

MA 21.1 Tue 9:30 HSZ 101

Ultrafast control of spin-spin interactions 2D antiferromagnetic layers — •Alireza Qaiumzadeh — Center for Quantum Spintronics, Norwegian University of Science and Technology

Light enables the ultrafast, direct, and nonthermal control of the spin-spin interactions.

In this work, we consider two types of antiferromagnetic systems: 1. A 2D honeycomb lattice antiferromagnetic spin-orbit Mott insulator, and 2. A 2D metallic Rashba antiferromagnetic system.

Based on the Floquet theory and time-dependent perturbation theory, we demonstrate that by changing the amplitude and frequency of polarized laser pulses, one can tune the amplitudes and signs of and even the ratio between the exchange and Dzyaloshinskii-Moriya spin interactions. Furthermore, the renormalizations of the spin interactions are independent of the helicity. Our results pave the way for ultrafast optical spin manipulation in recently discovered two-dimensional magnetic materials.

[1] J. M. Losada, A. Brataas, and A. Qaiumzadeh, Phys. Rev. B 100, 060410(R) (2019). [2] S. Ø. Hanslin, A. Brataas, and A. Qaiumzadeh,

to be submitted (2020).

MA 21.2 Tue 9:45 HSZ 101

Ultrafast dynamics of itinerant and localized magnetic moments in antiferromagnetic $GdRh_2Si_2$ — •Sang-Eun Lee[1], Yoav William Windsor[1], Daniela Zahn[1], Kristin Kliemt[2], Cornelius Krellner[2], Denis V. Vyalikh[3], and Laurenz Rettig[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]Goethe-Universität Frankfurt, Frankfurt am Main, Germany — [3]DIPC, San Sebastián, Spain

The magnetic ordering in rare-earth based compounds is governed by the indirect exchange interaction (RKKY interaction) between the large, localized 4f-moments of the rare-earth atoms, mediated via the itinerant, weakly spin-polarized conduction electron bath. Yet how this coupling is active on an ultrafast timescale is still a matter of debate. $GdRh_2Si_2$ is an intermetallic model system, consisting of Gd layers stacked antiferromagnetically along the c-axis, separated by Si-Rh-Si slabs, which act as mediators for the RKKY interaction. Si-terminated surfaces of this compound have been shown to host metallic surface states at the surface Brillouin zone corners which become spin polarized due to the RKKY interaction below T_N [1]. Employing time- and angle-resolved photoemission spectroscopy (trARPES), and time-resolved resonant magnetic X-ray diffraction (trRXRD), we investigate the ultrafast dynamics of itinerant surface state electrons, and of long-range ordered localized magnetic moments, respectively. Combining these results, we will discuss the implications for the RKKY interaction and the demagnetization pathway in this antiferromagnetic compound.

[1] M. Güttler et al., Sci. Rep. 6, 24254 (2016)

MA 21.3 Tue 10:00 HSZ 101

Ultrafast excitation across the transition between antiferromagnetic phases. — •Yoav William Windsor[1], Daniela Zahn[1], Sang-Eun Lee[1], Kristin Kliemt[2], Cornelius Krellner[2], and Laurenz Rettig[1] — [1]Fritz-Haber-Institut der MPG (DE) — [2]Goethe-Universität Frankfurt (DE)

Antiferromagnetic spintronics are a promising route towards more efficient and stable devices. The prospect of employing antiferromagnets in devices opens new functionality pathways through properties that are not available with ferromagnets. One promising direction is light induced variations of the long-range spin arrangement.

Here we study Ho $4f$ spin dynamics in $HoRh_2Si_2$, a material with two antiferromagnetic phases with different spin arrangements: a high-T phase, in which all spins align (anti)parallel to [001], and a low-T phase in which they tilt by $\sim 30^\circ$ away from [001]. This is a change in the local 4f anisotropy, caused by variations in the crystal field.

We excite the low-T phase with a femtosecond optical laser pulse and probe the antiferromagnetic order's response using time-resolved resonant X-ray diffraction. Using the anisotropy of magnetic scattering, we decouple demagnetization dynamics from spin-tilting dynamics. These dynamics are distinctly different, demonstrating that AF order and collective spin rearrangement do not evolve together upon excitation (unlike upon heating). We identify two regimes: excitation within the low-T phase, and exciting from low-T to the high-T phase. Implications on the crystal field and its relation to the RKKY coupling between the Ho $4f$ moments will be discussed.

MA 21.4 Tue 10:15 HSZ 101

Strain generation via two-photon absorbtion in Bi:YIG visualized with UXRD — •Steffen Peer Zeuschner[1,2], Jan-Etienne Pudell[1], Alexander von Reppert[1], Marwan Deb[1], Elena Popova[3], Niels Keller[3], Matthias Rössle[2], Marc Herzog[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Wilhelm-Conrad-Roentgen Campus, BESSY II, 12489 Berlin, Germany — [3]Groupe d'Etude de la Matiére Condensée (GEMaC), CNRS UMR 8635, Université Paris-Saclay, 78035 Versailles, France

By ultrafast X-ray diffraction (UXRD) we quantify the strain from coherent and incoherent phonons generated by one- and two-photon absorption in bismuth-doped yttrium iron garnet (Bi:YIG). This ferrimagnetic insulator is a workhorse for laser-induced spin dynamics that may be excited indirectly via phonons. We identify the two-photon absorption by the quadratic fluence dependence of the transient strain and confirm a short lifetime of the intermediate state via the inverse proportional dependence on the pump-pulse duration. From this, we estimate the two-photon absorption coefficient at 800nm using the linear relation between strain and absorbed energy density. For below band gap excitation, large fluences of about 100 mJ/cm2 and a pulse duration of 120 fs lead to considerable strain amplitudes of 0.1% which are driven exclusively by two-photon absorption.

MA 21.5 Tue 10:30 HSZ 101

Ultrafast lattice dynamics of 3d ferromagnets — •Daniela Zahn[1], Florian Jakobs[2], Tim Butcher[3], Thomas Vasileiadis[1], Yoav William Windsor[1], Dieter Engel[4], Helene Seiler[1], Yingpeng Qi[1], Unai Atxitia[2], Jan Vorberger[3], and Ralph Ernstorfer[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [2]Freie Universität Berlin, Berlin, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [4]Max-Born-Institut, Berlin, Germany

The behavior of ferromagnets after laser excitation is governed by the interplay of electrons, lattice and spins. In the case of 3d-ferromagnets, strong coupling between electrons and spins leads to ultrafast demagnetization on the femtosecond time scale. The lattice plays an important role in the magnetization dynamics, since it drains energy from the electrons on similar timescales and absorbs angular momentum from the spin system. Here, we study the lattice response of the 3d ferromagnets nickel, iron and cobalt directly using femtosecond electron diffraction (FED). We find excellent agreement of the experimental results with DFT calculations in combination with a modified two-temperature model (TTM) that assumes strong coupling between electrons and spins. In addition, we compare the experiment to atomistic spin simulations. Our results suggest that energy transfer between electrons and spins on ultrafast timescales has a strong effect on the lattice dynamics.

MA 21.6 Tue 10:45 HSZ 101

Photoinducing coherent Teraherz spin dynamics without spin waves — •M. Terschanski[1], S. Dal Conte[2], F. Mertens[1], G. Springholz[3], A. Bonanni[3], G. Uhrig[4], G. Cerullo[2], D. Bossini[1], and M. Cinchetti[1] — [1]Experimentelle Physik VI, TU Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund, Germany — [2]Dipartimento di Fisica, Politecnico di Milano, Piazza L. da Vinci 32, 20133 Milano, Italy — [3]Institut fuer Halbleiterphysik, University of Linz, Altenberger Straße 69, 4040 Linz, Austria — [4]Theoretische Physik I, TU Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

Ultrafast coherent spin dynamics is generally induced generating magnon modes at their specific frequencies and according to their selection rules. Here we present a different approach: First, absorption measurements of hexagonal bulk α-MnTe revealed a coupling between the magnetic order and the band gap energy E_g below the Neél temperature ($T_N = 307$ K): a contribution to E_g proportional to the sublattice magnetization $\vec{M}$ was observed. Second, in a pump-probe experiment a 5 THz coherent phonon was induced, modulating the band-gap energy and thus the reflectivity of MnTe. Finally, we perform time-resolved magneto-optical measurements to assess whether the photo-induced band-gap dynamics affect the spin system. The temperature dependence of the magneto-optical signal proves that a 5 THz oscillation of the sublattice magnetization is driven by the band-gap dynamics. We thus disclose the excitation of coherent THz spin dynamics without the generation of magnons.

MA 21.7 Tue 11:00 HSZ 101

Spin-lattice dynamics from isotropic and anisotropic exchange — •Danny Thonig[1], Jacob Persson[2], Johan Hellsvik[3,4], Lars Nordström[2], Manuel Pereiro[2], and Jonas Fransson[2] — [1]School of Science and Technology, Örebro University, SE-70182 Örebro, Sweden — [2]Department of Material Theory, Uppsala University, Sweden — [3]Department of Physics, KTH Royal Institute of Technology, SE-106 91 Stockholm, Sweden — [4]Nordita, SE-106 91 Stockholm, Sweden

The understanding how magnons couple with phonons is of fundamental importance. It is dominantly caused by distance dependent exchange between the magnetic moment, such as RKKY-like Heisenberg or dipole-dipole interaction. Both exhibits changes in the magnetic order, say from ferro to antiferromagnetic states, related to the crystal structure, which is affected by displacements and call for deeper studies.

We report on an investigation of atomistic coupled spin-lattice dynamics by means of the Landau-Lifshitz-Gilbert and Newton equation. The exchange and force constant parameters of the Hamiltonian are approached by RKKY, Dzyaloshinskii-Moriya, and dipole-dipole interaction as well as Born-Landé exchange, respectively.

For low dimensional systems, we focus on the evolution from disordered to ordered states in dependence on temperature, island size, and external magnetic field. It turns out that spin and displacements have a crucial influence on each other, especially near magnetic order changes.

MA 21.8 Tue 11:15 HSZ 101

First-principles theory of laser-induced dynamics on the magnetic Dy_2Ni_2(DMF) complex — •Bharadwaj C. Mummaneni, Stefan Sold, Georgios Lefkidis, and Wolfgang Hübner — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany

We study the functional role of *d* and *f* electrons in the tetraheteronuclear Dy_2Ni_2(DMF) magnetic complex, which harbors a great potential as a magnetic-logic-element building block in future nanospintronic devices [1]. We focus on the theoretical characterization of the magnetic properties and the laser-induced spin dynamics of the complex, which adopts a defect dicubane geometry and has a ferromagnetic electronic ground state [2].

The highly correlated electronic excited states are computed with the state-of-the-art equation-of-motion coupled-cluster method and the perturbative inclusion of spin-orbit coupling. We are able to theoretically explain the experimental electronic absorption spectrum, as well as several time-resolved differential absorption spectra, after two different pump pulses (at 300 and 400 nm, respectively).

[1] D. Chaudhuri, G. Lefkidis, and W. Hübner, Phys. Rev. B **96**, 184413 (2017)
[2] D. K. C. Mondal, G. E. Kostakis, Y. Lan, W. Wernsdorfer, C. E. Anson, and A. K. Powell, Inorg. Chem. **50**, 11604 (2011)
[3] S. Sold, G. Lefkidis, B. Kamble, J. Berakdar, and W. Hübner, Phys. Rev. B **97**, 184428 (2018)

15 min. break.

MA 21.9 Tue 11:45 HSZ 101

Elucidating the mechanism for all-optical switching by tuning the femtosecond pulses into the infrared wavelength range — Robin John[1], •Jakob Walowski[1], Cai Müller[2], Marco Berritta[3], Deninse Hintzke[4], Oksana Chubykalo-Fesenko[5], Tiffany Santos[6], Henning Ulrichs[7], Ritwik Mondal[4], Peter Oppeneer[3], Ulrich Nowak[4], Jeffrey McCord[2], and Markus Münzenberg[1] — [1]Greifswald University, Greifswald, Germany — [2]Kiel University, Kiel, Germany — [3]Uppsala University, Uppsala, Sweden — [4]Konstanz University, Konstanz, Germany — [5]CSIC, Madrid, Spain — [6]Western Digital, San Jose, CA, United States — [7]Göttingen University, Göttingen, Germany

The energy transfer from electrons to spins upon laser excitation is the basis for the response dynamics, it determines the speed of ultrafast magnetization. In FePt nanoparticles, a material developed for heat-assisted magnetic recording, all-optical writing has been demonstrated by Lambert et al. in Science 2014. In the current understanding of the interaction of ultrafast excitation and heating, the influence of magnetic dichroism MCD and the presence of the inverse Faraday effect IFE jointly work as forces causing magnetization reversal.

We calculate the switching rates of the individual FePt nanoparticles in ab-initio calculations of the optical effects (IFE and MCD induced heating) included in thermal modelling, which provide switching rates for the ensembles. This theoretical description allows us to optimize the required number of shots to write the magnetization in experiments and optimize the process by tuning the laser fluence and wavelength.

MA 21.10 Tue 12:00 HSZ 101

Influence of the inverse Faraday effect on ultrafast switching processes in ferro- and antiferromagnets — •Tobias Dannegger[1], Marco Berritta[2], Severin Selzer[1], Ulrike Ritzmann[2,3], Peter M. Oppeneer[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, D78457 Konstanz, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Dahlem Center of Complex Quantum Systems and Department of Physics, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Ultrafast all-optical magnetisation reversal has been of interest due to its promising potential in the development of fast magnetic recording devices. This talk presents atomistic spin dynamics simulations used with input from DFT calculations [1] to study the role of the inverse Faraday effect (IFE) in laser-induced switching processes in ferro- and antiferromagnetic spin systems, specifically $L1_0$-ordered FePt and CrPt. The magnitude of the magnetisation induced by the IFE as well as the duration for which it remains present after the laser pulse are varied as parameters. The simulation results for FePt show, in agreement with previous results [2], that single-pulse switching in FePt is not possible but the IFE can, at least for certain parameter values, significantly enhance the switching probability. In antiferromagnets, the faster dynamics of the spin system make those materials more susceptible to the influence of the optically induced magnetisation.

[1] M. Berritta et al. Phys. Rev. Lett. **117**, 137203 (2016)
[2] R. John et al. Sci. Rep. **7**, 4114 (2017)

MA 21.11 Tue 12:15 HSZ 101

The orbital angular momentum of light in ultrafast magnetism — •Eva Prinz[1,2], Stephan Wust[1], Martin Stiehl[1], Jonas Hoefer[1], Benjamin Stadtmüller[1], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

Optical fields can carry an orbital angular momentum (OAM) in helical beams with an azimuthal phase dependence. Since its discovery in 1992 [1], a variety of applications for the OAM of light has been brought forward, such as data storage, quantum cryptography, astronomy, communication, enhanced sensitivity in imaging techniques and optical tweezers [2].

Our research is focused on exploring potential effects of the orbital angular momentum of light on both laser-induced ultrafast demagnetization and all-optical switching (AOS). The light-matter interactions could be influenced either by a transfer of angular momentum from photons to the electron system, or by the induction of a magnetic field in the material via the inverse Faraday effect. We present first measurements of both time-resolved MOKE and MOKE-microscopy pumped with OAM light.

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

MA 21.12 Tue 12:30 HSZ 101

Thermally induced magnetic switching in GdFeCo using picosecond laser pulses - experiment vs theory — Florian Jakobs[1], Thomas Ostler[2], Jon Gorchon[3], and •Unai Atxitia[1] — [1]Fachbereich Physik, Freie Universität Berlin Germany — [2]Dèpartement de Physique, Universitè de Liege — [3]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, USA

There are still many open questions about the driving mechanisms behind ultrafast magnetic switching in GdFeCo alloys by a single femtosecond (fs) optical pulse. Phenomenological models suggest a fs-scale exchange relaxation between the sublattices, which would limit the stimuli time a fs-scale. However the recent observations of single-pulse switching with either optical, or electrical stimuli of up to ten picosecond, have questioned this previous understanding. In this work, we aim to bridge this gap of knowledge. To that end, we have studied single-pulse optical switching, both experimentally and theoretically, for a wide range of system parameters, such as composition, laser power and pulse duration. For the first time we have found excellent quantitative agreement between our atomistic spin model and experiments across a broad range of compositions and laser durations ranging from fs to ps. Furthermore we explore numerically the impact of various switching parameters, that are typically unaccessible to experiments. Such as Gd-concentration, element-specific relaxation parameter, pulse duration and fluence. In agreement with previous experiments, we find the conditions for switching up to pulse durations close to ten ps.

MA 21.13 Tue 12:45 HSZ 101

All Optical Switching in FePtCr Alloys — •Stephan Wust[1], Martin Stiehl[1], Nataliia Schmidt[2], Ritwik Mondal[3], Benjamin Stadtmüller[1,4], Ulrich Nowak[3], Manfred Albrecht[2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern — [2]Institute for Physics, University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg, Germany — [3]Universität Konstanz, Universitätsstraße 10, 78464 Konstanz, Germany — [4]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany

The speed of magnetic data storage and information processing technologies is particularly important for magnetic device performances but currently limited to a few nanoseconds. In this regard, all-optical switching (AOS) is a highly promising effect to overcome this limit. Here, we focus on the AOS phenomena and the corresponding fs magnetization dynamics in $L1_0$ ordered FePt thin films doped with Cr.

For investigating the effect of optical excitation, we employ magneto-optical-effects to image the optically induced change of magnetic domains in real space. For a Cr concentration of 5%, we observe a helicity-dependent switching. Since this effect happens with an efficiency below 100%, parameters like sample thickness and temperature are systematically varied to optimize the switching process. We compare this experimental finding for different Cr concentrations to gain insight into the role of the dopant for the observed magnetization reversal. Our results are an important step towards a deeper understanding of AOS in FePt based materials.

MA 21.14 Tue 13:00 HSZ 101

Ultrafast magnetization switching in a model system of alloys with exchange coupling - a parameter study — •Kai Leckron and Hans Christian Schneider — University of Kaiserslautern, Department of Physics

Optically induced deterministic switching was demonstrated in GdFeCo with antiferromagnetic coupling between the sublattices [1] and theoretically related to thermal effects [2,3].

We study antiferromagnetically coupled-sublattice dynamics in a model consisting of two subsystems with itinerant and localized single-particle states [4]. After an instantaneous excitation of the itinerant subsystem we dynamically calculate the carrier dynamics in both subsystems using Boltzmann scattering integrals for exchange scattering processes. In agreement with Ref. [4], we find that on ultrashort time scales (some 10 fs) exchange dominates over Elliott-Yafet like spin-flip scattering.

We identify parameter regions where the so called "transient ferromagnetic state" appears and others where even a revearsal of the magnetization occurs. We also find a connection between the existence of a compensation temperature in the equilibrium magnetization curve and the magnetization switching, which is in agreement with recent atomistic simulations [5].

[1] Radu et al., Nature 472, 205 (2011) [2] J. H. Mentink et al., Phys. Rev. Lett. 108, 057202 (2012) [3] T. A. Ostler, Nat. Commun. 3, 666 (2012) [4] A. Baral and H. C. Schneider, Phys. Rev. B 91, 100402(R) (2015) [5] Moreno et al., Phys. Rev. B 99, 184401 (2019)

MA 22: Frustrated Magnets - Spin Liquids 1 (joint session TT/MA)

Time: Tuesday 9:30–13:00 Location: HSZ 304

MA 22.1 Tue 9:30 HSZ 304

Low temperature thermal transport studies on the kagome quantum spin liquid candidate herbertsmithite — Jan Bruin, •Ralf Claus, Yosuke Matsumoto, Jürgen Nuss, Masahiko Isobe, and Hidenori Takagi — Max Planck Institute for Solid State Research, Stuttgart, Germany

Quantum spin liquids (QSLs) are a novel state of matter that may host exotic excitations like itinerant charge-neutral spin-1/2 quasiparticles (spinons). The prototype for a QSL ground state is the spin-1/2 Heisenberg antiferromagnet on the kagome lattice. In terms of materials, herbertsmithite ($ZnCu_3(OH)_6C_{12}$) provides a perfect realization of this model. However, despite theoretical and experimental efforts the nature of its ground state remains under debate. An important question concerns the existence of an excitation gap.

To address this issue, we performed thermal transport measurements down to 80 mK. The measurement of the thermal conductivity (k) only captures mobile excitations in the material and is therefore a powerful tool to detect low-lying (gapless) spinons. In our measurements, we confirmed the absence of a finite k/T (spinon) term but observed a robust T-squared power-law behavior. I will discuss the possible QSL ground state scenarios in detail as well as an unusual field dependence.

MA 22.2 Tue 9:45 HSZ 304

Magnetic properties of the $NaYbO_2$ and $KYbO_2$ triangular antiferromagnets — •Franziska Grussler, Sebastian Bachus, Philipp Gegenwart, and Alexander A. Tsirlin — Centerfor Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

$NaYbO_2$ and $KYbO_2$ feature the same space group $R\bar{3}m$ as the spin-liquid candidate $YbMgGaO_4$ but evade structural disorder pertinent to that compound. We report a comparative study of these triangular antiferromagnets including their structural characterization and thermodynamic properties in the milli-K temperature range. Both $NaYbO_2$ and $KYbO_2$ reveal magnetic interactions of about 4 K and no signs of magnetic order in zero field, but undergo field-induced magnetic order that in the Na case occurs between 3 T and 8 T. By studying specific heat of $NaYbO_2$ at milli-K temperatures, we conclude that between 0.5 T and 2 T, within the putative spin-liquid phase, magnetic specific heat follows quadratic behavior expected for the gapless Dirac spin liquid. In zero field, no simple power-law behavior can be observed, but the data clearly deviated from an activated behavior expected for a gapped ground state. Our observations establish gapless nature of the spin-liquid phase of triangular antiferromagnets.

MA 22.3 Tue 10:00 HSZ 304

NMR and bulk magnetometry investigations of the field-induced order in the frustrated triangular-lattice compound $NaYbSe_2$ — •S. Luther[1,2], K. M. Ranjith[3], T. Reimann[1], Ph. Schlender[4], B. Schmidt[3], J. Sichelschmidt[3], H. Yasuoka[3], J. Wosnitza[1,2], Th. Doert[4], M. Baenitz[3], and H. Kühne[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]MPI for Chemical Physics of Solids, Dresden, Germany — [4]Faculty of Chemistry and Food Chemistry, TU Dresden, Germany

The Yb-based delafossite $NaYbSe_2$ is a triangular-lattice antiferromagnet with space group (R-3m). In this compound, spin-orbit coupling leads to a pronounced magnetic anisotropy. The absence of magnetic long-range order at zero field is suggestive of a quantum spin-liquid ground state. From specific-heat and magnetization experiments, magnetically ordered states were observed for $H \perp c$ and $H \parallel c$ exceeding 2 and 9 T, respectively. ^{23}Na ($I = 3/2$) NMR probes the microscopic details of the field-induced magnetic structure. Measurements of the $1/T_1$-relaxation rate are consistent with the specific-heat data. At $H \perp c = 5$ T, the magnetization indicates an up-up-down spin arrangement with according asymmetric broadening of the NMR spectra. At $H \parallel c = 16$ T, an umbrella-type configuration of the magnetic moments is revealed, in agreement with a symmetric broadening of the NMR spectra. Low-field measurements reveal a continuous increase of the $1/T_1$-relaxation rate and spectral broadening without signatures of long-range order down to 0.3 K.

MA 22.4 Tue 10:15 HSZ 304

Spin orbit entangled $J = 1/2$ triangular magnets $NaYbCh_2$ (Ch:O,S,Se): pushing a spin liquid into criticality and magnetic order by magnetic fields — •M. Baenitz[1], K.M. Ranjith[1], S. Luther[3], Ph. Schlender[2], T. Reimann[3], S. Khim[1], J. Sichelschmidt[1], B. Schmidt[1], H. Yasuoka[1], H. Kuehne[3], J. Wosnitza[3], and Th. Doert[2] — [1]MPI for Chemical Physics of Solids, D-01187 Dresden, Germany — [2]TU Dresden, Department of Chemistry and Food Chemistry, D-01062 Dresden, Germany — [3]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, D- 01328 Dresden, Germany

Spin orbit coupling (SOC) brought significant progress to the field of quantum spin liquids (QSLs). Yb-based magnets are prime candidates for the QSL-state and as such the $NaYbCh_2$ series is regarded as a unique platform to study anisotropic planar spin 1/2 triangular lattice magnetism (TLM) with bond frustration. In contrast to $YbMgGaO_4$,which shares the same space group (R-3m), $NaYbCh_2$ lacks inherent lattice distortions and Yb resides on a centrosymmetric position in the $YbCh_6$ octahedron. Our comprehensive study combines bulk- and local- probes and identifies $NaYbCh_2$ as a new class of spin orbit entangled TLMs were the QSL state is realized on a perfect triangular lattice [1,2]. The application of fields in (a,b)-plane transforms the system into a critical regime followed by long range order. We present magnetization, specific heat and Na NMR data down to 300 mK

[1] M. Baenitz et al., Phys. Rev. B 98 (2018)
[2] K.M. Ranjith et al., Phys. Rev. B 99 (2019)

MA 22.5 Tue 10:30 HSZ 304

Spin dynamics in the quantum spin liquid candidate $Na_2BaCo(PO_4)_2$ probed by Electron Spin Resonance —

•Christoph Wellm[1,2], Willi Roscher[1], Vladislav Kataev[1], Oleg Janson[1], Bernd Büchner[1,2], Robert J. Cava[3], and Ruidan Zhong[3] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, D-01069 — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, D-01062 — [3]Department of Chemistry, Princeton University, Princeton, US-08544

The triangular-lattice magnet $Na_2BaCo(PO_4)_2$ with localized effective spin-1/2 moments of Co^{2+} ions shows strong, exotic magnetic flucuations in absence of long-range order down to 0.3 K with large residual entropy and linear in temperature spinon excitations, making it a very promising candidate for the realization of a quantum spin liquid [1,2]. We report electron spin resonance (ESR) and magnetization results of powder and single crystals of the title compound supporting the scenario of a spin liquid. We relate our results to previous experimental studies [1,2] and theory (talk by W. Roscher et.al. at this conference).

[1] R. Zhong *et al.*, Proc. Natl. Acad. Sci., **116**, pp. 14505-14510 (2019)
[2] N. Li *et al.*, arXiv:1911.11107 (2019)

MA 22.6 Tue 10:45 HSZ 304

DFT calculations of the quantum spin liquid candidate $Na_2BaCo(PO_4)_2$ — •Willi Roscher, Christoph Wellm, Bernd Büchner, Vladislav Kataev, and Oleg Janson — Leibniz Institute for Solid State and Materials Research Dresden, Germany

The recently synthesized triangular lattice magnet $Na_2BaCo(PO_4)_2$ shows effective $S = 1/2$ behavior with strong quantum fluctuations persistent down to 50 mK, rendering it as a candidate for the quantum spin liquid (QSL) ground state [1,2]. Very recent ESR and magnetization measurements hint at a more complex picture with different energy scales. To provide a microscopic insight, we perform band structure DFT calculations using the full-potential code FPLO. We calculate the band structure and Wannier projections for the t_{2g} an e_g states of Co. The evaluated transfer integrals are used to estimate the leading magnetic exchanges, the spin orbit coupling constant and the trigonal crystal field splitting. These two latter parameters are used to assess the electronic ground state and the excitation spectrum of Co^{2+} atoms. Finally, we compare our theoretical findings with new experimental studies.

[1] R. Zhong *et al.*, Proc. Natl. Acad. Sci., **116**, pp. 14505-14510 (2019)
[2] N. Li *et al.*, arXiv:1911.11107 (2019)

MA 22.7 Tue 11:00 HSZ 304

Evidence of one-dimensional magnetic heat transport in the triangular-lattice antiferromagnet Cs_2CuCl_4 — E. Schulze[1,2], S. Arsenijevic[1], L. Opherden[1], A.N. Ponomaryov[1], J. Wosnitza[1,2], T. Ono[3], H. Tanaka[4], and •S.A. Zvyagin[1] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, 01328 Dresden, Germany — [2]TU Dresden, 01062 Dresden, Germany — [3]Osaka Prefecture University, Osaka 599-8531, Japan — [4]Tokyo Institute of Technology, Tokyo 152-8551, Japan

We report on low-temperature heat-transport properties of the spin-1/2 triangular-lattice antiferromagnet Cs_2CuCl_4. Broad maxima in the thermal conductivity along the three principal axes, observed at about 5 K, are interpreted in terms of the Debye model, including the phonon Umklapp scattering. For thermal transport along the b axis, we found a pronounced field-dependent anomaly, close to the transition into the three-dimensional long-range-ordered state. No such anomalies were observed for the transport along the a and c directions. We argue that this anisotropic behavior is related to an additional heat-transport channel through magnetic excitations, that can best propagate along the direction of the largest exchange interaction. Our observations strongly support the quasi-1D spin-liquid scenario with spinons as elementary excitations, proposed for this frustrated antiferromagnet. Besides, peculiarities of the heat transport of Cs_2CuCl_4in magnetic fields up to the saturation field and above are discussed [1].

This work was supported by the DFG.

[1] E. Schulze et al., Phys. Rev. Research 1, 032022(R) (2019).

15 min. break.

MA 22.8 Tue 11:30 HSZ 304

Thermal conductivity of the hyper-hyperkagome spin liquid candidate $PbCuTe_2O_6$ — •Xiaochen Hong[1], Matthias Gillig[1], Shravani Chillal[2], A. T. M. Nazmul Islam[2], Bernd Büchner[1,3,4], Bella Lake[2,5], and Christian Hess[1,4] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden (IFW-Dresden), Dresden — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin — [3]Institute of Solid State Physics, TU Dresden, Dresden — [4]Center for Transport and Device, TU Dresden, Dresden — [5]Technische Universität Berlin, Berlin

Quantum spin liquids (QSLs) are exotic phases of matter formed by interacting quantum spins. QSLs are characterized by the absence of static magnetism and the existence of emergent fractional excitations. Recently, $PbCuTe_2O_6$ was discovered to be a rare QSL candidate with a three-dimensional spin structure. Here we report the thermal conductivity measurements of this compound down to about 50 mK and up to 16 T. Our results show evidence for the gapped spinons in $PbCuTe_2O_6$. Besides, the unusual field dependence of its low temperature thermal conductivity indicates the residual magnetic order is very sensitive to the external field.

MA 22.9 Tue 11:45 HSZ 304

Probing anisotropic static and dynamic magnetic interactions of Fe-kagome $Fe_4Si_2Sn_7O_{16}$ by bulk magnetisation and NMR — •S. Dengre[1], R. Sarkar[1], L. Opherden[2], M. Uhlarz[2], T. Herrmannsdörfer[2], M. Allison.[3], T. Söhnel[3], C.D. Ling[4], J Gardner[5], and H.-H. Klauss[1] — [1]Institute of Solid State and Materials Physics, TU Dresden, 01062 Dresden, Germany — [2]Institute of Resource Ecology and Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany — [3]School of Chemical Sciences, University of Auckland, Auckland 1142, New Zealand — [4]School of Chemistry, The University of Sydney, Sydney 2006, Australia — [5]Australian Centre for Neutron Scattering, Australian Nuclear Science and Technology Organization, Menai 2234, Australia

$Fe_4Si_2Sn_7O_{16}$ hosts an undistorted kagome lattice with Fe^{2+} ($3d^6$, $S = 2$) spins. We present results on oriented and unoriented powder samples. The bulk magnetic susceptibility shows the presence of strong planar (XY) rather than *Ising* anisotropy. Both static NMR shift (K) and dynamic spin-lattice relaxation rate ($1/T_1$) NMR reveal a highly anisotropic behaviour in $\parallel$ and $\perp$ orientation of the external field with respect to the Kagome planes. For $\parallel$ orientation, the NMR shift (K) scales linearly with the bulk susceptibility for temperatures ranging from 100 K to 4 K. The NMR shift in $\perp$ orientation shows the onset of AFM correlations at T $\approx$ 30 K by a deviation from the linear scaling. This is also reflected in the $1/T_1$ for $\parallel$ orientation, which starts to decrease at T $\approx$ 30 K.

MA 22.10 Tue 12:00 HSZ 304

Dynamics of an SU(2)-symmetric Kitaev model: spectroscopic signatures of fermionic magnons — •Willian Massashi Hisano Natori[1] and Johannes Knolle[1,2,3] — [1]Imperial College London, London, United Kingdom — [2]Technische Universitat Munchen, Garching, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

In this work, we study the dynamics of an integrable Kugel-Khomskii Hamiltonian defined as an extension of the Kitaev honeycomb model. This model displays a global SU(2) symmetry that leads to S=1 fermionic excitations. We show that these fermions' dynamical response is exactly computed using a few-particle approach and can be experimentally probed with resonant inelastic x-ray scattering. The techniques developed to uncover the dynamics of the Kitaev model are used to compute the expected neutron scattering response. We show that the SU(2) symmetric model exhibits a vison gap three times larger than the spin-1/2 Kitaev model and a broader band of excitations due to the presence of additional Majorana flavors.

MA 22.11 Tue 12:15 HSZ 304

Phonon renormalization in the Kitaev quantum spin liquid — •Alexandros Metavitsiadis and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, D-38106 Braunschweig, Germany

We present the self-energy of phonons, magnetoelastically coupled to the two-dimensional Kitaev spin-model on the honeycomb lattice. Fractionalization of magnetic moments into mobile Majorana matter and a static $\mathbb{Z}_2$ gauge field lead to a continuum of relaxation processes comprising two channels. Thermal flux excitations, which act as an emergent disorder, strongly affect the phonon renormalization. Above the flux proliferation temperature, the dispersion of a narrow quasiparticle-hole channel is suppressed in favor of broad and only weakly momentum dependent features, covering large spectral ranges. Our analysis is based on complementary calculations in the low-temperature homogeneous gauge and a mean-field treatment of thermal gauge fluctuations, valid at intermediate and high temperatures.

MA 22.12 Tue 12:30 HSZ 304

Phase Diagram of the Breathing Kagome $S = 1/2$ XY Model with Four-Site Ring Exchange — •Niklas Casper and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, Germany

We study the phase diagram of the breathing kagome $S = 1/2$ XY model with four-site ring exchange. This model exhibits trimerization of the nearest neighbor exchange between up-/downward oriented triangles of the kagome lattice. This may be of relevance to compounds like vanadium oxyfluoride $[NH_4]_2[C_7H_{14}N][V_7O_6F_{18}]$.

Though a frustrated quantum spin model, it does not suffer from the sign problem and therefore can be treated by quantum Monte Carlo. In particular, we use the stochastic series expansion method which is extended to treat four-site ring exchange terms residing on the up to next nearest neighbor bow-tie plaquettes by using an update procedure proposed by Roger G. Melko and Anders W. Sandvik [Phys. Rev. E **72**, 026702].

Results for the spin stiffness will be presented in order to study the quantum phase transition belonging to the 3D XY universality class.

MA 22.13 Tue 12:45 HSZ 304

Chromium breathing pyrochlores as a showcase for a variety of pyrochlore Hamiltonians — •Tobias Müller[1], Pratyay Ghosh[2], Yasir Iqbal[3], Ronny Thomale[1], Johannes Reuther[4], Michel J. P. Gingras[5,6], and Harald O. Jeschke[7] — [1]Institute for Theoretical Physics and Astrophysics, Julius-Maximilians University of Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Paul Scherrer Institut, Forschungsstrasse 111, 5232 Villigen PSI, Schweiz Switzerland — [3]Department of Physics, Indian Institute of Technology Madras, Chennai 600036, India — [4]Dahlem Center for Complex Quantum Systems and Fachbereich Physik,Freie Universität Berlin, 14195 Berlin, Germa — [5]epartment of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada — [6]Quantum Materials Program, Canadian Institute for Advanced Research, MaRS Centre,West Tower 661 University Ave., Suite 505, Toronto, ON, M5G 1M1, Cana — [7]Research Institute for Interdisciplinary Science, Okayama University, Okayama 700-8530, Japa

We investigate all six structurally characterized chromium-based breathing pyrochlores using a combination of density functional theory and pseudofermion functional renormalization group calculations. We show that the variety of chemical compositions leads to distinct magnetic behavior due to the different pyrochlore Hamiltonians realized. We discuss especially the line-like degeneracies in momentum space found in sulfide compounds and an approximate spiral spin liquid in a selenide material. The root cause for these effects are longer-rage exchange couplings up to third nearest neighbor type.

MA 23: Functional Antiferromagnetism

Time: Tuesday 9:30–13:15 Location: HSZ 401

MA 23.1 Tue 9:30 HSZ 401

Bloch lines in antiferromagnetic domain walls — •L. Kuerten[1], M. C. Weber[1], E. Hassanpour[1], M. Trassin[1], Y. Tokunaga[2], Y. Taguchi[3], Y. Tokura[4], Th. Lottermoser[1], and M. Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Department of Advanced Materials Science, University of Tokyo, Japan — [3]RIKEN Center for Emergent Matter Science, Japan — [4]Department of Applied Physics, University of Tokyo, Japan

Bloch lines are topological defects in magnetic domain walls at which the magnetic chirality of the wall changes. While Bloch lines in ferromagnets have been extensively investigated, they have only been theoretically predicted in antiferromagnets. Here, we use low-temperature magnetic force microscopy to resolve Bloch lines in an antiferromagnetic domain wall for the first time. We perform our experiments in the orthoferrite $DyFeO_3$, which transforms from a ferromagnetic to an antiferromagnetic phase at low temperature. By tracking the magnetic structure across the transition, we show that domains in one phase transform into domain walls of the other phase and vice-versa. We propose that antiferromagnetic Bloch lines emerge from previously existing Bloch lines in domain walls of the ferromagnetic phase – constituting the transfer of a topological defect of the spin structure across a phase transition.

MA 23.2 Tue 9:45 HSZ 401

Current-induced electrical switching of antiferromagnetic MnN — •Mareike Dunz[1], Tristan Matalla-Wagner[1], and Markus Meinert[2] — [1]Center for Spinelectronic Materials and Devices, Department of Physics, Bielefeld University — [2]Department of Electrical Engineering and Information Technology, TU Darmstadt

Electrical switching and readout of antiferromagnets allows to exploit the unique properties of antiferromagnetic materials in nanoscopic electronic devices. Recently, it was shown that switching of magnetic moments via spin-orbit torque is possible in epitaxial films of antiferromagnetic NiO [1]. A spin-polarized current is generated in adjacent Pt layers and exerts a torque on the magnetic moments in the antiferromagnetic film. Here, we report experiments on spin-orbit torque induced switching of a polycrystalline, metallic antiferromagnet with low anisotropy and high Néel temperature [2]. We demonstrate the switching in a Ta / MnN / Pt trilayer system, deposited by (reactive) magnetron sputtering. The dependencies of the switching amplitude, efficiency, and relaxation are studied with respect to the MnN film thickness, sample temperature and current density. Our findings are consistent with a thermal activation model and resemble to a large extent previous measurements on CuMnAs and Mn_2Au, which exhibit similar switching characteristics due to an intrinsic spin-orbit torque.

[1] T. Moriyama et al., Sci Rep. 8, 14167 (2018)
[2] M. Dunz et al., arXiv : 1907.02386v2

MA 23.3 Tue 10:00 HSZ 401

Mechanism of Néel Order Switching in Antiferromagnetic Thin Films — Lorenzo Baldrati[1], Olena Gomonay[1], Andrew Ross[1,2], Mariia Filianina[1,2], Romain Lebrun[1], Rafael Ramos[3], Cyril Leveille[1], •Felix Fuhrmann[1], Thomas Forrest[4], Francesco Maccherozzi[4], Sergio Valencia[5], Florian Kronast[5], Eiji Saitoh[3], Jairo Sinova[1], and Mathias Kläui[1,2] — [1]Johannes Gutenberg-University Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]WPI-Advanced Institute for Materials-Research, Tohoku University, Japan — [4]Diamond Light Source, Oxfordshire, United Kingdom — [5]Helmholtz-Zentrum Berlin, Germany

Antiferromagnetic insulators (AFMI) are promising candidates for spintronics. They have the potential for ultrafast operation, scalability, due to the lack of stray fields and insensitivity against external magnetic fields. While reading of the Néel order orientation **n** can be achieved electrically via the spin Hall magnetoresistance [1], the electrically writing of **n** is still a challenge. Here we show that one can electrically switch the antiferromagnetic moments with current pulses. The current is applied to a heavy metal (HM) to achieve spin accumulation by the spin hall effect at the AFMI-HM interface, exerting anti-damping like torques on the AFMI [2,3]. The resulting switching was investigated electrically and imaged by x-ray magnetic dichroism [4]. [1] Baldrati et al., PRB 98, 024422 (2018). [2] Moriyama et al., Sci. Rep. 8, 14167 (2018). [3] Chen et al., PRL 120, 207204 (2018). [4] Baldrati et al., PRL 123, 177201 (2019).

MA 23.4 Tue 10:15 HSZ 401

Epitaxial Mn2Au thin films for antiferromagnetic spintronics grown by molecular beam epitaxy — •Satya Prakash Bommanaboyena[1], Stanislav Bodnar[1], Mariia Filianina[1], René Heller[2], Thomas Bergfeldt[3], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Institut für Angewandte Materialien, Karlsruher Institut für Technologie, Germany

The recent experimental realization of Néel order switching in antiferromagnetic Mn2Au [1] has sparked a huge interest in the growth of high-quality films of this compound. We report the preparation of high-quality epitaxial Mn2Au(001) thin films using molecular beam epitaxy. Mn and Au were co-evaporated at low deposition rates in ultra-high vacuum onto a heated epitaxial Ta(001) buffer layer deposited on Al2O3 substrates. Structural and morphological characterization of the films was carried out using reflective high energy electron diffraction, x-ray diffraction, x-ray reflectometry and temperature dependent resistance measurements. The films were found to be highly crystalline and smooth with a low defect concentration. Rutherford backscattering spectrometry and inductively coupled plasma optical emission spectroscopy were employed to determine their composition. Additionally, X-ray magnetic linear dichroism-photoemission electron microscopy was used to study their antiferromagnetic domain pattern. [1] S. Yu. Bodnar et al Nature Communications 9, 2018.

MA 23.5 Tue 10:30 HSZ 401

Spin-flop induced resistance modifications of antiferromagnetic Mn2Au thin films — •Stanislav Bodnar[1], Yurii Sckourski[2], Satya Prakash Bommanaboyena[1], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 7, 55128 Mainz, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Recently it has been shown that the Néel vector in Mn2Au can be switched by the application of current pulses via Néel spin-orbit torques [1]. The process of Néel vector switching was visualized by XMLD-PEEM [2]. In our work we report about the effect of magnetic field induced spin-flop transitions in antiferromagnetic Mn2Au(001) on the resistance of the samples. Two contributions of spin=flop induced resistance changes were observed on different time scales [3]. The first contribution gives rise to resistance reductions of ~1% and decay on a time scale of seconds. The second contribution is identified as a persistent anisotropic magnetoresistance effect, with a magnitu of ~0.1%. The results indicate that the origin of current induced large resistance modifications in Mn2Au are associated with domain wall resistance.

[1] S. Yu. Bodnar et al., Nat. Commun. 9, 348 (2018) [2] S. Yu. Bodnar et al., Phys. Rev. B 99, 140409(R) (2019) [3] S. Yu. Bodnar et al., arXiv 1909.12606 (2019).

MA 23.6 Tue 10:45 HSZ 401

Néel vector induced manipulation of valence states in the collinear antiferromagnet Mn2Au — •Hans-Joachim Elmers[1], S. V. Chernov[1], S. P. Bommanaboyena[1], S. Yu. Bodnar[1], K. Medjanik[1], S. Babenkov[1], O. Fedchenko[1], D. Vasilyev[1], S. Y. Agustsson[1], C. Schlueter[2], A. Gloskovskii[2], Y. Matveyev[2], Y. Skourski[3], S. Dsouza[4], J. Minar[4], L. Šmejkal[1], J. Sinova[1], M. Klaeui[1], G. Schoenhense[1], and M. Jourdan[1] — [1]Institut für Physik, Universität Mainz, Germany — [2]DESY, Hamburg, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]University of West Bohemia, Czech Republic

Manipulation of the electronic valence states of the collinear metallic antiferromagnet Mn_2Au was achieved by reorienting the direction of the staggered magnetisation (Néel vector). Pulsed magnetic fields of 50 T were used to direct the sublattice magnetisations of capped epitaxial Mn_2Au (001) thin films perpendicular to the applied field direction by a spin-flop transition. The electronic structure was investigated by hard X-ray angular-resolved photoemission spectroscopy [1]. Our results confirm that the magnetic order parameter in real space provokes considerable changes of electronic states in reciprocal space near the Fermi Level and close to the X points. [1] J. Synchr. Rad. 26, 1996 (2019)

MA 23.7 Tue 11:00 HSZ 401

Tetragonal CuMnAs: Phase stability and finite temperature magnetism — •Karel Carva, Pavel Baláž, David Wagenknecht, and Klára Uhlířová — Charles University, DCMP, Ke Karlovu 5, CZ-12116, Prague, Czechia

The antiferromagnetic semimetal CuMnAs has a high application potential in spintronics. A controlled rotation of magnetic moments' orientation by means of an applied electrical field has been demonstrated in tetragonal CuMnAs, employing spin-orbit torques. However, bulk CuMnAs natively crystallizes in the orthorhombic phase, which has different interesting properties. Tetragonal CuMnAs phase has been achieved in epitaxially deposited samples or by inserting lattice defects linked to non-stoichiometry in CuMnAs [1]. The tendency towards tetragonal phase with an increased Cu content has been confirmed by ab initio calculations [1].

We have estimated the stability of different phases and calculated formation energies of possible defects in the alloy. Mn_{Cu} and Cu_{Mn} antisites and vacancies on Mn or Cu sublattices were identified as most probable defects in CuMnAs. We estimated also the in-plane resistivity of CuMnAs with defects of low formation energies. Finally, we have determined the exchange interactions and estimated the Néel temperature of the ideal and disordered AFM-CuMnAs [2]. A good agreement with the experimental data makes it possible to estimate the structure and composition of real CuMnAs samples.

[1] K. Uhlířová et al., J. Alloys Compd. 771, 680 (2018)
[2] F. Máca et al., Phys. Rev. B 96, 094406 (2017)

15 min. break

MA 23.8 Tue 11:30 HSZ 401

Geometry-induced effects in antiferromagnetic spin chains — Denys Y. Kononenko[1,2], •Oleksandr V. Pylypovskyi[3,2], Ulrich K. Roessler[1], Kostiantyn V. Yershov[1,4], Artem V. Tomilo[2], Jeroen van den Brink[1], Yuri Gaididei[4], Denys Makarov[3], and Denis D. Sheka[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [4]Bogolyubov Institute for Theoretical Physics, Kyiv, 03143, Ukraine

Antiferromagnetic nanostructures as objects with ultrahigh eigenfrequencies and low sensitivity to demagnetizing fields are promising candidates for applications in data storage and information processing. Three-dimensional architectures enable new ways for tuning magnetic responses and extend ideas of spintronic devices. Here, we analyze anitferromagnetically ordered curvilinear spin chains and derive a Lagrangian taking into account the exchange interaction and effective anisotropy arising from the dipolar interaction. The static and dynamic properties of the spin system are influenced by emergent geometry-induced anisotropies and Dzyaloshinskii–Moriya interaction, which are illustrated by ring and helix geometries as case studies. Ground states and coupling of spin wave modes due to curvilinear geometry are described.

MA 23.9 Tue 11:45 HSZ 401

Anomalous and topological Hall effects in epitaxial thin films of the noncollinear antiferromagnet Mn_3Sn — •James M. Taylor[1], Anastasios Markou[2], Edouard Lesne[1], Pranava Keerthi Sivakumar[1], Peter Werner[1], Claudia Felser[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale), Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany

Noncollinear antiferromagnets with a $D0_{19}$ hexagonal structure have garnered much attention for their potential applications in topological spintronics. Here, we report the deposition of continuous epitaxial thin films of such a material, Mn_3Sn, with both (0001) c-axis orientation and $(40\bar{4}3)$ texture. In the latter case, the thin films exhibit a small uncompensated Mn moment in the basal plane, quantified via magnetometry. This cannot account for the large anomalous Hall effect simultaneously observed in these films, even at room temperature, with magnitude σ_{xy} ($\mu_0 H = 0$ T) = 21 Ω^{-1}cm^{-1} and coercive field $\mu_0 H_c = 1.3$ T. We attribute the origin of this anomalous Hall effect to momentum-space Berry curvature arising from the symmetry-breaking inverse triangular spin structure of Mn_3Sn. Upon cooling through the transition to a glassy ferromagnetic state at around 50 K, a peak in the Hall resistivity close to the coercive field indicates the onset of a topological contribution to Hall effect. This is due to the emergence of a scalar spin chirality generating a real-space Berry phase, and is controllable using different field cooling conditions.

MA 23.10 Tue 12:00 HSZ 401

Nonlinear photocurrents in antiferromagnets — •Maximilian Merte[1], Frank Freimuth[1], Jan-Philipp Hanke[1,2], Wanxiang Feng[1,3], Stefan Blügel[1], Lukasz Plucinski[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099Mainz, Germany — [3]School of Physics, Beijing Institute of Technology, Beijing 100081, China

In the field of spintronics, the interaction of antiferromagnets with external electromagnetic fields plays a crucial role for future prospects related to fundamental understanding and technological applications. In materials of reduced symmetry a photocurrent which is of second order in the electric field can occur. Recently a response tensor describing these currents was derived based on the non-equilibrium Keldysh formalism [1]. Here we want to report on the implementation of this second order response tensor by means of by means of Wannier interpolation, which can be applied as a postprocessing step to first-principles calculations performed with the Jülich DFT code FLEUR [2]. We apply the developed method to study photocurrents of linear and circular polarized light in antiferromagnets. – We acknowledge funding from DFG through SFB/TRR 173 and computing resources granted by JARA-HPC from RWTH-Aachen University and Forschungszentrum Jülich under projects jara0161, jiff40 and jias1a. [1] Frank Freimuth *et al.*, arXiv: 1710.10480 (2017) [2] www.flapw.de

MA 23.11 Tue 12:15 HSZ 401

Resistivity in Antiferromagnetic System with Domain Wall — •Jun-Hui Zheng, Alireza Quaiumzadeh, and Arne Brataas — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

The ballistic and diffuse transport through a ferromagnetic domain wall (DW) has been well studied for decades. In some cases, the DW serves as an effective barrier potential, increasing the resistance. Antiferromagnetic systems have a more complicated magnetic structure and their DWs have more exotic properties, which has attracted theoretical and experimental attention. Here we theoretically study the resistance due to the antiferromagnetic domain wall scattering by using the adiabatic approximation. Depending on the types of antiferromagnetism, the resistance shows rather different behaviors.

MA 23.12 Tue 12:30 HSZ 401

Propagation length of antiferromagnetic magnons governed by domain configurations — •Andrew Ross[1,2], Romain Lebrun[1], Olena Gomonay[1], Asaf Kay[3], Daniel A. Grave[3], Lorenzo Baldrati[1], Florian Konst[4], Alireza Qaiumzedah[5], Arne Brataas[5], Avner Rothschild[3], Rembert Duine[5,6,7], and Mathias Kläui[1,2,5] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]Technion-Israel Institute of Technology, Israel — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [5]Center for Quantum Spintronics, Trondheim, Norway — [6]Utrecht University, The Netherlands — [7]Eindhoven University of Technology, The Netherlands

Antiferromagnetic (AF) insulators benefit from unparalleled stability in external fields, magnetisation dynamics in the THz range, a lack of stray fields and low Gilbert damping, which should allow for efficient long-range propagation of magnons[1,2]. Here we investigate the underlying mechanisms behind magnon transport in AF thin films. We show efficient spin transport is possible across μm in nm thick thin films, contrary to previous studies reporting nm spin-diffusion lengths [3]. To understand this, we perform XMLD imaging of the AF domains to evidence their role in the propagation of magnons. We achieve efficient control over the AF system and establish the possibility to propagate long-distance spin-waves in AF thin films. [1] Chumak et al., Nature Phys. 11, 6 (2015), [2] Lebrun et al., Nature 561, 222 (2018), [3] Cramer et al., J. Phys. D: Appl. Phys. 51, 14 (2018)

MA 23.13 Tue 12:45 HSZ 401

Chiral Logic Computing with Twisted Modes in Antiferromagnetic Magnonic Waveguides — •Alexander F. Schäffer[1], Min Chen[2], Chenglong Jia[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle (Saale), Germany — [2]Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education & Institute of Theoretical Physics, Lanzhou University, China

Antiferromagnetic (AFM) materials are demonstrated to offer a new exciting platform for ultrafast information processing with low cross talks and good compatibility with existing technology. Particularly interesting for energy-saving computing are low-energy AFM excitations, or magnons. For an AFM waveguide we prove the existence of chiral magnonic eigenmodes that possess a well-defined projection of the angular momentum (AM) along the wave propagation direction. The AM is an unbounded integer determined by the spatial topology of the respective mode and is shown to be exploitable for multiplex AFM magnonic computing. We demonstrate how a variety of symmetry and topology protected logic gates can be realized and operated without Joule heating. A Dzyaloshinskii-Moriya interaction arising at the waveguide boundary allows for a coupling to an external electric field and results in a Faraday effect. Our findings uncover a new aspect of AFM spintronics and point to a novel route to communicating and handling data swiftly, with high fidelity and at low energy cost.

MA 23.14 Tue 13:00 HSZ 401

Antiferromagnetic cavity optomagnonics — •tahereh parvvini[1], victor bittencourt[2], and silvia viola kusminskiy[3] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany — [3]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany

We propose a cavity optomagnonic system based on antiferromagnetic insulators. We derive the Hamiltonian of the system and obtain the coupling of the antiferromagnetic magnon modes to the optical cavity field as a function of magnetic field and material properties. We show that, in the presence of hard-axis anisotropy, the optomagnonic coupling can be tuned by a magnetic field applied along the easy axis, allowing to bring a selected magnon mode into and out of a dark mode. For easy-axis antiferromagnets the coupling is instead independent of the magnetic field. We study the dynamic features of the driven system including optically induced magnon amplification and cooling, Purcell enhancement of transmission, and induced transparency, and discuss their experimental feasibility.

MA 24: Magnetic Heusler Compounds

Time: Tuesday 9:30–11:45 Location: HSZ 403

MA 24.1 Tue 9:30 HSZ 403

Quadratic magnetooptic Kerr effect spectroscopy on partially ordered Co_2MnSi Heusler compounds — •Robin Silber[1], Daniel Král[2], Ondřej Stejskal[2], Lukáš Beran[2], Jaromír Pištora[1], Martin Veis[2], Timo Kuschel[3], and Jaroslav Hamrle[2] — [1]IT4Innovations,VŠB - Technical University of Ostrava, Czech Republic — [2]Charles University, Prague, Czech Republic — [3]Bielefeld University, Germany

The Heusler compound Co_2MnSi provides a crystallographic transition from B2 to $L2_1$ structure with increasing annealing temperature [1]. Here, we present linear and quadratic magnetooptic Kerr effect (LinMOKE and QMOKE) spectroscopy [2,3] for a set of Co_2MnSi thin-film samples annealed from 300°C to 500°C. Two interesting features were observed: (i) for photon energy below 3.0 eV, the shape of QMOKE spectra have resonance (sharp peak-like) features, an unusual behaviour for metallic systems. (ii) The amplitude of these peaks is proportional to the annealing temperature and thus, to the amount of $L2_1$ ordering. While this dependence has been shown for a single wavelength before (1.95 eV) [4], we present this proportionality for the whole studied spectral range. The $L2_1$ ordering affects the interband contributions of the LinMOKE and QMOKE spectra, which are compared to ab-initio calculations.

[1] O. Gaier et al., J. Appl. Phys. 103, 103910 (2008)
[2] R. Silber et al., Phot. Nano. Fund. Appl. 31, 60 (2018)
[3] R. Silber et al., Phys. Rev. B 100, 064403 (2019)
[4] G. Wolf et al., J. Appl. Phys. 110, 043904 (2011)

MA 24.2 Tue 9:45 HSZ 403

Spin-Resolved Bulk Electronic Structure Analysis of the Half-Metallic Heusler Ferromagnet Co_2MnSi — •S. Chernov[1], S. Babenkov[1], D. Vasilyev[1], K. Medjanik[1], O. Fedchenko[1], M. Jourdan[1], S. Andrieu[2], C. Guillemard[2], F. Bertran[3], P. LeFevre[3], M. Schmitt[4], C. Schlueter[5], Yu. Matveyev[5], A. Gloskowski[5], R. Claessen[4], H.-J. Elmers[1], and G. Schönhense[1] — [1]JGU Mainz, Germany — [2]Université de Lorraine, Nancy, France — [3]Synchrotron SOLEIL-CNRS, Gif-sur-Yvette, France — [4]Universität Würzburg, Germany — [5]DESY, Hamburg, Germany

The spin-resolved bulk electronic structure of the half-metallic ferromagnet Co_2MnSi was studied by HAXPES (beamline P22, PETRA III, Hamburg) using ToF *k*-microscopy [1], exploiting the large information depth of up to 20 nm. High-quality MBE films on MgO(100) were capped by 1 nm Au or 2 nm MgO; both showed clear Kikuchi-type photoelectron-diffraction patterns after transport under air. High-symmetry planes ΓKX and XUW were identified varying hν (3-5.3 keV). The photoemission intensities show clear band dispersion for both samples. The spin-resolved HAXPES data confirm that bulk Co_2MnSi is a half-metallic ferromagnet with the top of the minority band at the Γ-point, in accordance with theory [2]. Comparison with measurements on uncapped films at hν=30 eV [3] and 6 eV [4] allows to disentangle bulk and surface states.

[1] K. Medjanik et al., J. Synchr. Rad. 26, 1886 (2019); [2] http://heusleralloys.mint.ua.edu; [3] C. Guillemard et al., Phys. Rev. Appl. 11, 064009 (2019); [4] S. Chernov et al., arXiv 1910.05205 (2019)

MA 24.3 Tue 10:00 HSZ 403

Theoretical Approach for Simulation of the Magnetic and Magnetocaloric properties of Ni-Mn-Ga Heusler Alloys — •Olga Miroshkina, Vladimir Sokolovskiy, Danil Baigutlin, Mikhail Zagrebin, and Vasiliy Buchelnikov — Chelyabinsk State University, 454001 Chelyabinsk, Russia

In this paper, we study the magnetic and magnetocaloric properties of Ni1+xMn1-xGa (x = 0.16, 0.18, and 0.3) Heusler alloys. These compositions belong to the three different regions of the (T-x) phase diagram and illustrate different sequences of phase transitions. The study is performed using the theoretical model based on the Malygin theory of the smeared phase transitions, Bean-Rodbell theory of the first-order phase transitions, and the mean-field theory. The temperature dependences of the deformation, magnetization, and isothermal entropy change of the alloys under study are investigated. It is shown that the largest change in magnetic entropy is observed for Ni2.18Mn0.82Ga, in which the martensitic transition is accompanied by a change in the magnetic ordering. The smallest change in entropy is found for Ni2.3Mn0.7Ga, in which the magnetocaloric effect is observed at ferro-paramagnetic phase transition in the martensite. However, the refrigeration capacity of this composition is twice as large as for the other considered ones. This is due to the fact that the temperature range in which the MCE takes place is significantly wider as compared to the other compositions considered. This work was supported by Russian Foundation for Basic Research No. 18-32-00507.

MA 24.4 Tue 10:15 HSZ 403

Anomalous Hall effect and spin orbit torques in tetragonal ferrimagnetic $Mn_{3-x}Pt_xGa$ thin films — •Dominik Kriegner[1,2,3], Anastasios Markou[1], Helena Reichlova[2], Richard Schlitz[2], Claudia Felser[1], and Sebastian T.B. Goennenwein[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]Institut für Festkörper- und Materialphysik, TU Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Institute of Physics, Academy of Science of the Czech Republic

We systematically study the variation of magnetization and anomalous Hall effect in $Mn_{3-x}Pt_xGa$ thin films as function of the Pt content and temperature. Since Mn and Pt share a lattice site and Mn occupies two distinct sites with ferrimagnetic arrangement of the magnetic moments, the system can be driven to a magnetic compensation point [1]. At this point $Mn_{3-x}Pt_xGa$ can behave similar to the well known antiferromagnetic half Heusler CuMnAs with which is shares its symmetry. CuMnAs was recently found to have a switchable antiferromagnetic order by a charge current induced staggered Neel spin orbit torque [2]. We propose to use $Mn_{3-x}Pt_xGa$ near the compensation point as a model system to study this spin orbit torque. Here the non-zero magnetization can be used to orient the ferrimagnetic order by moderate magnetic field to prepare the system in a defined state. The current induced torque, (i.e. the variation of the magnetization,) is obtained by homodyne detection and its effect is mapped out for various magnetization orientations. [1] R. Sahoo et al., Adv. Mater. 28, 8499 (2016) [2] P. Wadley et al., Science 351, 587 (2016)

MA 24.5 Tue 10:30 HSZ 403

Probing the spin textures by topological Hall effect in tetragonal inverse Heusler compounds — •Vivek Kumar[1,2], Nitesh Kumar[1], Manfred Reehuis[3], Jacob Gayles[1], Chandra Shekhar[1], Peter Adler[1], and Claudia Felser[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany — [2]Technische Universität München, München, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Heusler compounds having D_{2d} crystal symmetry gained much attention recently due to the stabilization of a vortex-like spin texture called antiskyrmions in thin lamellae of $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Here we present that bulk $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ undergoes a spin-reorientation transition from a collinear ferromagnetic to a non-collinear configuration of Mn moments below 135 K, which is accompanied by the emergence of a topological Hall effect. A unique feature of the present system is the observation of a zero-field topological Hall resistivity with a sign change which indicates the robust formation of antiskyrmions. Additionally, we investigate the two series of Heusler compounds $Mn_{1.4}Pt_{1-x}Pd_xSn$ ($0 \leq x \leq 0.3$) and $Mn_{1.4}Pt_{1-y}Rh_ySn$ ($0.1 \leq y \leq 0.8$). Our results demonstrate the tunability of topological spin textures in the Heusler system which paves the way for systematic design of antiskyrmion phase containing compounds suitable for applications in spintronics. [1]Nayak *et al.*, Nature **548**, 561 (2017).

MA 24.6 Tue 10:45 HSZ 403

Magnetic structure dependence on plate thickness in $Mn_{1.4}$PtSn single crystals — •Belen Zuniga[1,2], Peter Milde[1], Praveen Vir[2], Markus König[2], Claudia Felser[2], Andrew Mackenzie[2], and Lukas Eng[1] — [1]IAP, TU Dresden, 01187 Dresden, Germany — [2]MPI CPfS, 01187 Dresden, Germany

Materials with D_{2d} crystal symmetry potentially host a variety of different magnetic textures such as spin spirals or antiskyrmions, as theoretically predicted [1,2]. $Mn_{1.4}$PtSn is an acentric tetragonal Heusler compound that possesses such a symmetry and, furthermore, a helical ground state as well as an antiskyrmion lattice at room temperature when applying a small magnetic field [3].

We show that the *ab*-plane of bulk $Mn_{1.4}$PtSn exhibits ferromagnetic order, with high anisotropy and self-organization of domains. Applying magnetic force microscopy (MFM) we are able to discern magnetic structures with sizes ranging from ~ 10 μm down to ~ 100 nm. Preparing ultra-thin single-crystalline $Mn_{1.4}$PtSn samples, we find a critical sample thickness of 4.5 μm, below which the fractal-like magnetic domain patterns change into magnetic lamellar structures with submicron periodicity. Under a magnetic field, a lattice of bubble-like domains is induced into these crystalline thinned $Mn_{1.4}$PtSn samples, similar to skyrmion lattices that we have investigated by MFM [4,5]. References: [1] Bogdanov and Yablonskii, Sov. Phys. JETP 68 (1989) 101. [2] Koshibae and Nagaosa, Nat. Commun. 7 (2016) 10542. [3] Nayak et al., Nature 548 (2017) 561. [4] Milde et al., Science 340 (2013) 6136. [5] Készmárki et al., Nat. Mater. 14 (2015) 1116.

MA 24.7 Tue 11:00 HSZ 403

Magnetocrystalline anisotropy in Fe2Ni(Ga,Al): ab initio study — •Vladimir Sokolovskiy[1], Olga Miroshkina[1], Danil Baigutlin[1], Mikhail Zagrebin[1], Vasiliy Buchelnikov[1], and Markus Gruner[2] — [1]Chelyabinsk State University, Chelyabinsk, Russia — [2]University of Duisburg-Essen, Duisburg, Germany

Co(Fe)-Ni-Al(Ga) can be stand out among FSM alloys due to their high Curie temperature, which greatly simplifies the requirements for high-temperature FSM. Significantly, these materials are ductile, cheap, and easily synthesized. In this work we consider stoichiometric FSM Heusler alloys Co2NiAl, Fe2NiAl, and Fe2NiGa. For this compositions, first-principles investigation of the ground state properties was performed in the framework of density functional theory using Perdew, Burke, and Ernzerhof (PBE) approximation, which is the mostly widespread and successful. Using VASP package, we minimized the total energy for several types of structures (regular Heusler structure with Cu2MnAl-type, inverse Heusler one with Hg2TiCu-type, B2 disordered structure with Hg2TiCu-type, and layered disordered structure with Hg2TiCu-type) and determined the energetically favorable structure for compositions under study. For favorable structure, the equilibrium lattice parameter, total magnetic moment, and magnetocrystalline anisotropy were calculated.

This work was supported by RSF 17-72-20022.

MA 24.8 Tue 11:15 HSZ 403

Computational design of quaternary Heusler compounds for reconfigurable spintronic devices — •Thorsten Aull[1], Ersoy Şaşioğlu[1], Igor V. Maznichenko[1], Sergey Ostanin[1], Arthur Ernst[2], Ingrid Mertig[1], and Iosif Galanakis[3] — [1]Institue of Physics, Martin Luther University Halle-Wittenberg, D-06120 Halle (Saale), Germany — [2]Institute of Theoretical Physics, Johannes Kepler University Linz, Altenberger Straße 69, A-4040 Linz, Austria — [3]Department of Materials Science, School of Natural Sciences, University of Patras, GR-26504 Patras, Greece

Reconfigurable spin tunnel diodes and transistors are a new concept in spintronics which unify memory and logic in a single device [1]. The realization of such devices require the use of materials with unique spin-dependent electronic properties such as spin-gapless semiconductors (SGSs) and half-metallic magnets (HMMs). Quaternary Heusler compounds offer a platform to design within the same family of compounds HMM and SGS with similar compositions and lattice constants to make coherent growth of the consecutive spacers of the device possible. Employing the ab-initio calculations, we scan quaternary Heusler compounds and identify suitable candidates for reconfigurable spintronic devices combining the desirable properties [2]: (i) HMMs and SGSs with sizable spin gaps both below and above the Fermi level, (ii) high Curie temperature T_C, (iii) negative formation energies, and (iv) convex hull energy distance less than 200 meV.

[1] E. Şaşıoğlu et al., ACS Appl. Electron. Mater. **1**, 1552-1559 (2019).
[2] T. Aull et al., Phys. Rev. Materials (submitted).

MA 24.9 Tue 11:30 HSZ 403

Electron transport in the high-entropy alloy Al_xCrFeCoNi — •František Máca[1], Josef Kudrnovský[1], Václav Drchal[1], Ilja Turek[2], and Sergii Khmelevskyi[3] — [1]Institute of Physics CAS, Prague — [2]Institute of Physics of Materials CAS, Brno — [3]Institute for Applied Physics, Vienna University of Technology, Vienna

The high-entropy alloys Al_xCrFeCoNi exist over a broad range of Al concentrations ($0 < x < 2$). With increasing Al content their structure is changed from the fcc to bcc phase. We investigate the effect of such structural changes on transport properties including the residual resistivity and the anomalous Hall resistivity. We have performed a detailed comparison of the first-principles simulations with available experimental data.

We show that the calculated residual resistivities for all studied alloy compositions are in a fair agreement with available experimental data as concerns both the resisitivity values and concentration trends. We emphasize that a good agreement with experiment was obtained also for the anomalous Hall resistivity. We have completed study by estimation of the anisotropic magnetoresistance, spin-disorder resistivity, and Gilbert damping. The obtained results prove that the main scattering mechanism is due to the intrinsic chemical disorder whereas the effect of spin polarization on the residual resistivity is appreciably weaker.

[1] J. Kudrnovský at al., Phys. Rev. B **100** (2019) 014441

MA 25: Skyrmions I (joint session MA/TT)

Time: Tuesday 9:30–13:00 Location: POT 6

Invited Talk MA 25.1 Tue 9:30 POT 6

Emergent electromagnetic response of nanometer-sized spin textures — •Max Hirschberger — Department of Applied Physics, University of Tokyo, Bunkyo-ku 113-8656, Japan — RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan

A wide array of experimental techniques in condensed matter, including resonant elastic x-ray scattering and real-space imaging using Lorentz transmission electron microscopy, were incorporated to establish the presence of nanometer-sized skyrmion lattices in the new centrosymmetric materials Gd_2PdSi_3 and $Gd_3Ru_4Al_{12}$, with Heisenberg Gd^{3+} magnetic moments and competing interactions. When a conduction electron moves through a topological spin texture, it acquires a quantum mechanical phase (Berry phase) which can strongly modify the dynamical properties of the electron gas. The tiny topological spin textures (skyrmions) in Gd_2PdSi_3 and $Gd_3Ru_4Al_{12}$ are expected to give rise to a giant emergent magnetic field B_{em} of order 500 Tesla. We have recently found quantitative evidence for B_{em} using electrical Hall measurements and thermoelectric properties such as the topological Nernst effect. Ongoing work is focused on the tuning of magnetic interactions in these materials via chemical substitution; moreover, we are employing element-specific resonant x-ray scattering techniques to study the coupling between local moments and conduction electrons in this new class of skyrmion host.

MA 25.2 Tue 10:00 POT 6

Skyrmions in $SrRuO_3$ based heterostructures in tilted magnetic fields? — •Sven Esser[1], Sebastian Esser[1], Anton Jesche[1], Vladimir Roddatis[2], and Philipp Gegenwart[1] — [1]Experimentalphysik VI, Augsburg University, D-86159 Augsburg, Germany — [2]Interface Geochemistry, Helmholtz Centre Potsdam, 14473 Potsdam, Germany

Formation of Néel-type skyrmions at oxide interfaces is supported by Dzyaloshinskii-Moriya (DM) interaction through introducing a breaking of the inversion symmetry. Recently, artificial perovskite bilayers of the ferromagnetic metal $SrRuO_3$ (SRO) and spin-orbit semimetal $SrIrO_3$ (SIO) have been proposed to host two-dimensional Néel-type skyrmions [1].

Utilizing metal-organic aerosol deposition we have grown $[(SrIrO_3)_2/(SrRuO_3)_5]_k$ bilayers with $k = 1, 5, 10$ repetitions on cubic (001)-oriented $SrTiO_3$ substrate to investigate the interface induced changes of the electronic and magnetic properties. The fully epitaxially strained state of the thin films was verified by X-ray diffraction patterns in combination with reciprocal space mapping and TEM images. A contribution of the topological Hall effect to the Hall resistance can be observed for temperatures between 10K and 80K, which may hint at the formation of skyrmions.

Measurements of the angular-dependent Hall resistivity display additional contributions that are not observed in pure SRO thin films and thus most likely related to the SRO/SIO interface.

[1] J. Matsuno *et al.*, Science Adv. **2** (2016) e1600304.

MA 25.3 Tue 10:15 POT 6

Intrinsic stability of magnetic anti-skyrmions in tetragonal inverse Heuslers — •Rana Saha[1], Tianping Ma[1], Abhay K. Srivastava[1], Ankit Sharma[1], Jagannath Jena[1], Vivek Kumar[2], Praveen Vir[2], Claudia Felser[2], and Stuart Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

One of the major topics in spintronics today is the study of chiral non-collinear spin textures of various topologies. Recently, a novel chiral spin texture, magnetic anti-skyrmion that has distinct topological features from that of Bloch and Néel skyrmions, was discovered in tetragonal inverse Heusler, $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Anti-skyrmions have boundaries (the in-plane magnetization region between magnetization pointing up and pointing down) that have a complex structure consisting of successive left hand Bloch, left hand Néel, right hand Bloch, and right hand Néel wall segments. This complex structure is a result of an anisotropic Dzyaloshinskii-Moriya exchange interaction that is set by the symmetry of the underlying lattice. Interestingly, magnetic anti-skyrmions are stable over a wide range of temperature, magnetic field and thickness of the lamella in which they are formed [2]. In this presentation, I will discuss our recent in-situ Lorentz and magnetic force microscopic studies of nucleation, stabilization and size manipulation of anti-skyrmions in tetragonal inverse Heuslers.

[1]Nayak *et al.*, Nature **548**, 561 (2017).
[2]Saha *et al.*, Nat. Commun. **10**, 5305 (2019).

MA 25.4 Tue 10:30 POT 6

Crystal Hall effect in an ultrathin film of $SrRuO_3$(SRO) grown on $SrTiO_3$(STO)[001]: A case of collinear antiferromagnetic insulator — •Kartik Samanta[1], Marjana Ležaić[1], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany

Motivated by the recently observed topological Hall effect in ultra-thin films of SRO grown on STO(001) substrate, we investigate the magnetic ground state and anomalous Hall response of the SRO ultra-thin films by virtue of spin density functional theory(DFT). Our findings reveal that in the monolayer limit of SRO film, large energy level splitting of Ru-t_{2g} states, stabilizes an anti-ferromagnetic insulating magnetic ground state. For the doped insulating state, our calculated electronic transport properties based on Berry curvature analysis show a large Hall response. From the systematic investigation of our results, we find that the large Hall effect is due to a combination of broken time-reversal and crystal symmetries caused by the arrangement of non-magnetic atoms (Sr and O) in the mono-layer of SRO thin film. We identify the emergent Hall effect as a clear manifestation of the so-called crystal Hall effect [1] occurring in compensated antiferromagnets.

We acknowledge funding from the Deutsche Forschungsgemeinschaft (DFG) through SPP 2137 "Skyrmionics" and the Jülich Supercomputing Center(project JIFF40).

[1] L. Šmejkal, *et al.*; arXiv:1901.00445 (2019)

MA 25.5 Tue 10:45 POT 6

Topological Hall effect in thin films of tetragonal inverse Heusler compounds — •Anastasios Markou[1], Peter Swekis[1], Jacob Gayles[1], Dominik Kriegner[1,2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden

Spin chirality in metallic materials with noncoplanar spin structure gives rise to a Berry phase induced topological Hall effect (THE). Topologically stable nontrivial spin structures, such as skyrmions and antiskyrmions exhibit THE. The THE is a transverse response to an applied current that can be used to distinguish magnetic textures for device applications, such as the racetrack memory. We focus on the Heusler compounds with D_{2d} symmetry [1,2], which recently found to host antiskyrmions [2]. We present the structural, magnetic, and transport properties in thin films of the tetragonal Mn_xPtSn (x=1.4-2.1) and Mn_2RhSn Heusler compounds. We find that the THE appears below spin reorientation temperature, and together with the anomalous Hall effect are strongly dependent on the composition and thickness of the films.

[1]O. Meshcheriakova *et al.*, Phys. Rev. Lett. **113**, 087203 (2014).
[2]A. K. Nayak *et al.*, Nature **548**, 561-566 (2017).

MA 25.6 Tue 11:00 POT 6

Skyrmions in Ta/CoFeB-wedge/MgO — •Christian Denker[1], Hauke Heyen[1], Sören Nielsen[2], Malte Römer-Stumm[2], Nina Meyer[1], Neha Jha[1], Kornel Richter[2], Enno Lage[2], Markus Münzenberg[1], and Jeffrey McCord[2] — [1]Institut für Physik, Universität Greifswald, Germany — [2]Nanoscale Magnetic Materials - Magnetic Domains, Institute for Materials Science, Universität Kiel, Germany

We investigate different generation approaches as well as pinning center distribution and strength for magnetic skyrmions in Ta/CoFeB-wedge/MgO trilayers. Skyrmions appear as a part of the out-of-plane hysteresis or using pulsed in-plane fields and zero-field stable skyrmions result from tilted in-plane remanent magnetic field application. Furthermore, we investigate energy landscapes for skyrmions by current-induced hopping motion in a stripe with regions of different defect types and densities, since skyrmion motion tracking allows us to access the pinning center distribution and strength.

15 min. break.

MA 25.7 Tue 11:30 POT 6

Impact of light and heavy single atomic defects on single magnetic skyrmions — •Imara Lima Fernandes and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Incorporating magnetic skyrmions as future bits of information technology is challenged by the unavoidable defects inherent to any device. Recently, the universality of the skyrmion-defect interaction profiles for the 3*d* and 4*d* elements was established [1], which is mainly dictated by the defect-induced changes in the magnetic exchange interactions. Those defects can be used to enhance the skyrmions detection using all-electrical means via the spin-mixing magnetoresistance (XMR) [2,3]. In the current study based on a full *ab initio* approach, we explore impurities from various parts of the periodic table, which enable different mechanisms determining the skyrmion-defect interactions. We address systematically the case of vacancies, *sp* and 5*d* elements in order to find correlations between their chemical nature and the energetics as well as the electronic properties of skyrmions generated in Pd/Fe/Ir(111) surface.

– Funding provided by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 - DYNASORE).

[1] I. Lima Fernandes *et al.*, Nature Commun. **9**, 4395 (2018).
[2] I. Lima Fernandes *et al.*, arXiv:1906.08838, (2019)
[3] D. M. Crum *et al.*, Nature Commun. **6**, 8541 (2015)

MA 25.8 Tue 11:45 POT 6

Beyond Skyrmions Utilizing alternative magnetic quasi-particles for spintronics devices — •Börge Göbel[1,2], Oleg Tretiakov[3], Stuart S. P. Parkin[2], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [3]School of Physics, The University of New South Wales, Sydney, Australia

Skyrmions are considered as the bits in future spintronic devices like the racetrack storage. One issue, which is hindering the realization of this application, is the so-called skyrmion Hall effect: A skyrmion does not move parallel to an applied spin-polarized current. Instead, the skyrmion is pushed towards the edge of the sample where it annihilates. In this talk, I will give an overview about observed or proposed alternative magnetic quasiparticles. The stabilization, as well as the emergent electrodynamic effects will be discussed for the antiskyrmion, the antiferromagnetic skyrmion, the skyrmionium, and the bimeron. These magnetic objects are either attractive from a fundamental point of view, or are advantageous application-wise.

[1] B. Göbel, A. Mook, J. Henk, I. Mertig. PRB 96, 060406(R) (2017) [2] B. Göbel, A. Schäffer, J. Berakdar, I. Mertig, S. Parkin. Sci. Rep. 9, 12119 (2019) [3] B. Göbel, A. Mook, J. Henk, I. Mertig, O. Tretiakov. PRB 99, 060407(R) (2019) [4] B. Göbel, J. Henk, I. Mertig. Sci. Rep. 9, 9521 (2019)

MA 25.9 Tue 12:00 POT 6

Observation of anti-skyrmions in $Mn_2Rh_{0.95}Ir_{0.05}Sn$ Heusler compound — •Jagannath Jena[1], Rolf Stinshoff[2], Rana Saha[1], Abhay K. Srivastava[1], Tianping Ma[1], Hakan Deniz[1], Peter Werner[1], Claudia Felser[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany

Magnetic anti-skyrmions are topologically protected nanoscopic chiral spin textures. They are composed of alternating boundary of Bloch and Néel domain walls. Recently anti-skyrmions have been discovered in a ferromagnetic tetragonal inverse Heusler compound $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Here we report the observation of anti-skyrmions in a ferrimagnetic Heusler compound $Mn_2Rh_{0.95}Ir_{0.05}Sn$ using Lorentz transmission electron microscopy. This compound has a lower magnetic moment which orders at 270 K. Our results may pave the way to search for antiskyrmions in a ferrimagnetic material with a very low magnetic moment for future spintronic applications. [1]Nayak *et al.*, Nature **548**, 561 (2017).

MA 25.10 Tue 12:15 POT 6

B20-type MnSi films on Si (111) grown by flash lamp annealing — •Zichao Li[1,2], Yufang Xie[1,2], Viktor Begeza[1,2], Ye Yuan[1,3], Lars Rebohle[1], Manfred Helm[1,2], Kornelius Nielsch[2,4], Slawomir Prucnal[1], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany — [2]Technische Universität Dresden, D-01062 Dresden, Germany — [3]Songshan Lake Materials Laboratory, Dongguan, Guangdong 523808, People's Republic of China — [4]Institute for Metallic Materials, IFW-Dresden, Dresden, 01069, Germany

B20-type MnSi is one of the noncentrosymmetric materials hosting magnetic skyrmions, which are promising information carriers in spintronic devices. In this work, we report the preparation of (111)-textured MnSi films on Si substrates. The preparation method only includes the deposition of Mn layers at room temperature and a following process by flash lamp at milli-second. By controlling the thickness of Mn layers and flash energy, we can obtain pure MnSi or mixtures of MnSi and MnSi1.7. Surprisingly, all prepared films show Curie temperatures around 41 K, which is much higher than for bulk MnSi or films reported previously. Magnetic skyrmions are stabilized at the whole temperature range below 41 K and under a much wider magnetic-field range. We speculate that the increased Curie temperature is due to the strain in the MnSi films arising from the MnSi1.7 phase or from the substrate. Our work calls a re-examination of the structural and magnetic properties of B20 MnSi films.

MA 25.11 Tue 12:30 POT 6

Universality of energy barriers of large magnetic skyrmions —

•Jan Masell — Center for Emergent Matter Science RIKEN, Wako, Saitama, Japan

Magnetic skyrmions can only decay via singular spin configurations. We analyze the corresponding energy barriers of skyrmions for two distinct stabilization mechanisms, i.e., Dzyaloshinskii-Moriya interaction (DMI) and competing interactions [1]. Based on our numerically calculated collapse paths on an atomic lattice, we derive analytic expressions for the saddle-point textures and energy barriers of large skyrmions. The sign of the spin stiffness and the sign of fourth-order derivative terms in the classical field theory determines the nature of the saddle point and thus the height of the energy barrier. In the most common case for DMI-stabilized skyrmions (positive stiffness and negative fourth-order term) the saddle-point energy approaches a universal upper limit described by an effective continuum theory. For skyrmions stabilized by frustrating interactions, the stiffness is negative and the energy barrier arises mainly from the core of a singular vortex configuration.

[1] B. Heil, A. Rosch, and J. Masell, Phys. Rev. B 100, 134424 (2019)

MA 25.12 Tue 12:45 POT 6

The Chimera skyrmion collapse mechanism in harmonic transition state theory — •Stephan von Malottki[1], Pavel F. Bessarab[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]University of Iceland, Reykjavík, Iceland — [3]ITMO University, St. Petersburg, Russia

Recent studies reveal a new skyrmion annihilation mechanism via the Chimera skyrmion state [1-3]. We study the skyrmion lifetimes for this collapse mechanism in the ultrathin film system Pd/Fe/Ir(111) by a combination of nudged elastic band method calculations and harmonic transition state theory, based on an atomistic spin model parametrised from density functional theory [4]. The skyrmion lifetime has the form of an Arrhenius law and requires the energy barriers and prefactors of all relevant collapse mechanisms [5,6]. We address the crossover from the radial symmetric skyrmion collapse to the Chimera mechanism as well as the challenge of identifying and treating new Goldstone modes correctly.

[1] Meyer *et al.*, Nat. Commun. **10**, 3823 (2019)
[2] Heil *et al.*, Phys. Rev. B **100**, 134424 (2019)
[3] Desplat *et al.*, Phys. Rev. B **99**, 174409 (2019)
[4] von Malottki *et al.*, Sci. Rep. **7**, 12299 (2017)
[5] Bessarab *et al.*, Sci. Rep. **8**, 3433 (2018)
[6] von Malottki *et al.*, Phys. Rev. B **99**, 060409(R) (2019)

MA 26: Ultrafast Electron Dynamics II (joint session O/MA)

Time: Tuesday 10:30–13:30 Location: WIL B321

Invited Talk MA 26.1 Tue 10:30 WIL B321

Attosecond coherent manipulation of electrons in tunneling microscopy — •Manish Garg[1] and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany — [2]Institut de Physique, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

We demonstrate coherent manipulation of electrons in a tunnel junction of a scanning tunneling microscope, by tuning the carrier-envelope-phase (CEP) of two-cycle long (< 6 fs) optical pulses. We explore two different tunneling regimes at the tunnel junction, photon and field-driven tunneling and demonstrate transition from one to the other regime. Spatially localized and atomically strong electric fields of strength ~ 1V/Å substantially modulate the tunneling barrier on attosecond timescales, hence allowing taming of flow of electrons to either side of the tunnel junction. Capability to tune CEP with precision of less than 0.1π enables manipulation of electron tunneling at timescales of ~ 200 as. The strong atomic confinement of tunneling current induced by laser pulses enables optical-field driven tunneling microscopy. Real-time tracing of decay dynamics of oscillations of quasiparticles (localized-surface plasmon) in a gold nanorod is studied with a nanoscale probe in tunneling contact; enabling concurrently angstrom-scale and sub-fs resolution. We expect our results to enable inducing, tracking, and controlling electronic current at atomic scales and pave the way to petahertz coherent nanoelectronics and microscopy.

MA 26.2 Tue 11:00 WIL B321

Atomically resolved femtosecond pump probe measurements on Ta2NiSe5 — •Lukas Arnhold[1], Gregory McMurtrie[1], Shaoxiang Sheng[1], Mohamad Abdo[1,2], and Sebastian Loth[1,2] — [1]University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

The investigation of new and interesting phases in solids is one of the major goals of condensed matter physics. Ta2NiSe5, a putative excitonic insulator, is a material in which the exciton binding energy can exceed the band gap energy, leading to spontaneous condensation of excitons [1] following Bose-Einstein-statistics.

In such a material, it would be particularly interesting to locally break individual excitons and observe the re-condensation into the ground state.

To this end, we combine scanning tunneling microscopy (STM) with ultrafast THz light pulses. This boosts the STM's time resolution to the femtosecond range [2] making it possible to observe the fast electronic dynamics of correlated ground states in real space.

In static measurements, as we decrease the tunnel resistance, we observe a closing of the excitonic band gap. This closing coincides with an unusual increase of THz current in pump probe measurements. We study the dynamic response with atomic spatial resolution in particular around atomic defects in the surface layer.

[1] Lu, Y. et al., Nat Commun 8, 14408 (2017) [2] Cocker, T. et al., Nature Photon 7, 620*625 (2013)

MA 26.3 Tue 11:15 WIL B321

Ultrafast nano-imaging of the order parameter in a structural phase transition — •Thomas Danz, Till Domröse, and Claus Ropers — 4th Physical Institute – Solids and Nanostructures, University of Göttingen, Germany

Over the past decades, ultrafast optical techniques have considerably shaped our understanding of homogeneous materials, while transmission electron microscopy has greatly contributed to elucidating atomic structures and compositions on the sub-nanometer scale. Combining these concepts, ultrafast transmission electron microscopy allows for resolving femtosecond dynamics in heterogeneous materials using imaging, diffraction, and spectroscopy [1].

Here, we employ the Göttingen Ultrafast Transmission Electron Microscope (UTEM) [2] to demonstrate the ultrafast real-space mapping of the order parameter for a charge-density wave phase transition in the correlated material 1T-TaS_2. Specifically, we track the evolution of domain patterns on femtosecond to picosecond time and nanometer length scales, extracting characteristic observables not accessible by ultrafast electron or x-ray diffraction.

Additionally, we show that prominent features in the spatio-temporal domain evolution can be modeled in a time-dependent Ginzburg-Landau approach, allowing us to distinguish different regimes of the observed dynamics.

[1] A. H. Zewail, Science **328**, 187 (2010).
[2] A. Feist, Th. Danz *et al.*, Ultramicroscopy **176**, 63 (2017).

MA 26.4 Tue 11:30 WIL B321

Visualisation of coherent phonons in Bi_2Se_3 by time-resolved photoelectron diffraction — •Klara Volckaert[1], Davide Curcio[1], Dmytro Kutnyakhov[2], Steinn Agustsson[3], Kevin Bühlmann[4], Federico Pressacco[2], Michael Heber[2], Siarhei Dziarzhytski[2], Harald Redin[2], Yves Acremann[4], Jure Demsar[3], Wilfried Wurth[2], Charlotte E. Sanders[5], and Philip Hofmann[1] — [1]Aarhus University, Aarhus, Denmark — [2]DESY, Hamburg, Germany — [3]Johannes Gutenberg-University, Mainz, Germany — [4]ETH Zürich, Zürich, Switzerland — [5]Rutherford Appleton Laboratories, Harwell, United Kingdom

We have developed X-ray photoelectron diffraction (XPD) as a pump-probe technique allowing for the visualisation of structural changes on femtosecond timescales. We use this new technique to observe the structural dynamics of Bi_2Se_3 when excited by a 800 nm optical pump pulse. Terahertz oscillations of the fine structure within the resulting

XPD pattern were observed, which could originate from the excited $A_{1}g$ coherent phonons. These experiments were carried out at the FLASH free electron laser using a time-of-flight momentum microscope, which allows for simultaneous mapping of the emission angles in addition to kinetic energy of the electrons during a photoemission experiment (see D. Kutnyakhov et al. arXiv:1906.12155 (2019)).

MA 26.5 Tue 11:45 WIL B321

Radio frequency controlled electron pulses for time-resolved LEED — •Dennis Epp, Marcel Möller, Gero Storeck, and Claus Ropers — IV. Physical Institute, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Solid state surface systems display complex structural and electronic phases, with properties that may drastically differ from the bulk [1]. The coupling between electronic, lattice and spin degrees of freedom can be studied by ultrafast techniques. The recently developed method of Ultrafast Low-Energy Electron Diffraction (ULEED) is suitable for studying such structural dynamics on surfaces [2,3,4]. In this stroboscopic method, miniaturised laser-driven photoelectron sources generate ultrashort low-energy electron pulses to probe pump-induced changes to the surface structure [2,3], with a temporal resolution down to 1 ps. This contribution will focus on the characterization and control of low-energy electron beams by radio-frequency fields. First measurements of the beam properties resolved by a streaking field and further strategies for pulse compression will be discussed. [1] J. M. Kosterlitz. & D. J. Thouless, J. Phys. C 6, 1181*1203 (1973). [2] G. Storeck et al., Structural Dynamics 4, 044024 (2017). [3] S. Vogelgesang, et al., Nature Physics 14,184-190 (2018). [4] G. Horstmann et al., in preparation.

MA 26.6 Tue 12:00 WIL B321

VUV user station for femtosecond transmission, reflectivity and ellipsometry experiments — •Shirly Espinoza — ELI Beamlines. Institute of Physics. Czech Academy of Science. Czech Republic

Here, we present a versatile experimental platform, located in ELI Beamlines facility in the Czech Republic, dedicated to ultrafast pump-probe VUV absorption, transmission and ellipsometry with time resolution about 100 fs [1]. The whole system is based on a 30 mJ, 15 fs, 1 kHz in-house-developed laser with central wavelength 830 nm [2]. Its pulses are subsequently transformed into the desired pump and probe beams.

The platform is enclosed in an ultrahigh vacuum chamber equipped with reflective polarizing optics. This setup is equipped with a cryostat for measurements at temperatures from 20 K to 350 K. The upcoming upgrade with switchable Helmholtz coils will enable the experiments in magnetic field up to 1.5 T at 1 kHz. We present the experimental details of this cutting edge platform and discuss the possibilities that external scientists have to carry on their measurements on it.

Supported by the projects Structural dynamics of biomolecular systems (CZ.02.1.01/0.0/0.0/15-003/0000447) and Advanced research using high intensity laser produced photons and particles (CZ.02.1.01/0.0/0.0/16-019/0000789) from the European Regional Development Fund.

[1] S. Espinoza et al., Appl. Surf. Sci. 421, 378-382 (2017)
[2] F. Batysta et al., Opt. Express 24, 17843-17848 (2016)

Invited Talk MA 26.7 Tue 12:15 WIL B321

Ultrafast dynamics of charge transfer and Frenkel excitons in molecular thin films — •Benjamin Stadtmüller — University of Kaiserslautern and Research Center OPTIMAS, Erwin-Schroedinger-Str. 46, 67663 Kaiserslautern, Germany

Molecular complexes are highly flexible materials with intriguing opportunities for future photovoltaic and spintronic applications. The crucial device-relevant processes in molecular materials are the excited state dynamics and the carrier transport. Despite their common origin - the molecular band structure - their interplay is far from being understood. In this work, we focus on the link between the excited state dynamics of excitons in fullerene thin films and the resulting ensemble dynamics of the transport states of the entire film using time- and momentum resolved photoemission with fs-XUV radiation. Upon the optical excitation of excitons in C_{60} films, we reveal a transient modification of the energy level alignment of the molecular valence states, which can be identified as the signature of charge transfer (CT) excitons in molecular materials [1]. Taking advantage of this observation, we are able to disentangle the dynamics of CT and Frenkel excitons in (endohedral) fullerene films. We find different decay dynamics depending on the sample temperature or the charge doping concentration of the molecular film. Finally, we will provide a first view onto the momentum-space signature of CT and Frenkel excitons as a first step towards imaging the orbital character of both types of excitons in molecular films. [1] Nat. Commun. 10, 1470 (2019)

MA 26.8 Tue 12:45 WIL B321

Momentum resolved ultrafast organic molecular exciton dynamics — •Ralf Hemm, Martin Mitkov, Florian Haag, Sebastian Emmerich, Sebastian Hedwig, Martin Aeschlimann, and Benjamin Stadtmüller — University of Kaiserslautern (TUK) and research center OPTIMAS, Erwin-Schroedinger-Str.46, 67663 Kaiserslautern, Germany

Mapping the lowest unoccupied molecular orbitals (LUMOs) of an organic semiconducting thin film in momentum space is one of the great challenges of ultrafast surface science. Especially on the femto- to picosecond timescale, resolving the transient molecular orbital structure can help to disentangle excitonic decay mechanisms.

Here, we apply bichromatic time-resolved two-photon momentum microscopy [1] to image the excited state dynamics of excitons in molecular materials in momentum space. Our model system is a multilayer of ordered C60 on Cu(111), for which the energy dependent exciton dynamics was already reported in literature [2]. In this talk, we will therefore focus on the momentum space signatures of the excited states. We will identify the characteristic momentum space signatures of the excited states and follow their evolution above and below the critical temperature for the structural phase transition of C60. This will allow us to correlate the exciton dynamics in momentum space to the dominant energy and momentum dissipation process in molecular materials.

[1] F. Haag et al., Rev. Sci. Instr. 90, 103104 (2019)
[2] A. Rosenfeldt et al., J. Chem. Phys. 133, 23 (2010)

MA 26.9 Tue 13:00 WIL B321

Ultrafast excited state dynamics and transient band structure renormalizations in endohedral metallofullerenes — •Sebastian Hedwig, Sebastian Emmerich, Benito Arnoldi, Johannes Stöckl, Benjamin Stadtmüller, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern, Germany

Fullerenes have been object to intense research in the past decades, with promising potential for their implementation in optoelectronic devices. Embedding metal atoms or clusters into the fullerene by chemical synthesis can alter the cage symmetry, which strongly influences the molecular transport properties as well as the available relaxation channels of excited electronic states. Of special interest in this field is the cluster-cage electron transfer. Here, we present a time resolved photoemission study carried out on thin films of the prototypical endohedral metallofullerene $Sc_3N@C_{80}$ in a fs UV-pump XUV-probe experiment. We observe a transient broadening of all (polaronic) molecular valence states which follows the timescale of the exciton formation and decay in the molecular films, in analogy to our recent findings for the fullerene C_{60} [1]. Moreover, we show that the exciton and polaron dynamics are strongly altered upon K intercalation of the pristine film. This enables us to draw conclusions regarding cluster-cage charge transfer on ultrafast timescales. [1] B. Stadtmüller et al., Nat Commun 10, 1470 (2019)

MA 26.10 Tue 13:15 WIL B321

Temperature effects on the electron dynamics of metal-organic interface states — •Klaus Stallberg[1], Masahiro Shibuta[1,2], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Germany — [2]Keio Institute of Pure and Applied Sciences, Keio University, Yokohama, Japan

The presence of electronic interface states (IS) can strongly affect the electron dynamics at organic/metal interfaces. In particular, IS mediated charge transfer has been observed for model systems comprising few layers of π-conjugated organic molecules on single-crystalline metal surfaces. The formation of Shockley derived IS is well understood in the meantime and experimentally observed properties, such as the free-electron-like momentum dispersion as well as the energy onset, are well reproduced by *ab initio* calculations. In contrast, the IS electron dynamics eludes a consistent theoretical description so far, and systematic experimental studies are still missing.

Here, we systematically investigate temperature effects on the formation and the relaxation dynamics of the IS for the organic/metal systems NTCDA/Ag(111) and PTCDA/Ag(111). Using two-photon photoemission (2PPE), we observe a pronounced decrease of the IS energy for increasing temperatures, which we attribute to an extended molecule-metal binding distance due to phonons in the molecular layer. Moreover, a drastic increase of the IS lifetime with temperature is found. While it can qualitatively be explained with a reduced phase space for electron scattering with metal bulk states, this temperature effect is much stronger than expected from a simple physical model.

MA 27: Complex Oxides: Surfaces and Interfaces (jointly with DS, HL, KFM, MA, O) (joint session TT/MA/HL)

Time: Tuesday 14:00–15:45 Location: HSZ 02

MA 27.1 Tue 14:00 HSZ 02

Ultradense tailored vortex pinning arrays in $YBa_2Cu_3O_{7-\delta}$ thin films created by He ion beam irradiation — •Max Karrer[1], Bernd Aichner[2], Benedikt Müller[1], Vyacheslav Misko[3], Kristijan L. Mletschnig[2], Meirzhan Dosmailov[4], Johannes D. Pedarnig[4], Franco Nori[3], Reinhold Kleiner[1], Wolfgang Lang[2], and Dieter Koelle[1] — [1]Physikalisches Institut and Center for Quantum Science (CQ) in LISA+, Universität Tübingen, Germany — [2]Faculty of Physics, University of Vienna, Austria — [3]Theoretical Quantum Physics Group, RIKEN Cluster for Pioneering Research, Wako-shi, Saitama, Japan — [4]Institute of Applied Physics, Johannes Kepler University Linz, Austria

Magnetic fields penetrate a type II superconductor as magnetic vortices. In a clean superconductor they arrange in a hexagonal lattice; by addition of artificial pinning sites many other arrangements are possible. With a focused He ion beam, we fabricate periodic patterns of pinning sites with spacings down to 70 nm in $YBa_2Cu_3O_{7-\delta}$ thin films. In ultradense kagomé-like patterns, magnetic caging of vortices results in unconventional commensurability effects, yielding peaks in the critical current and minima in the resistance versus applied field up to ~ 0.4 T. The various vortex patterns at different magnetic fields are analyzed by molecular dynamics simulations of vortex motion, and the magnetic field dependence of the critical current is confirmed. These findings open the way for a controlled manipulation of vortices in cuprate superconductors by artificial sub-100 nm pinning landscapes.

[1] B. Aichner *et al.*, ACS Appl. Nano Mater. **2**, 5108–5115 (2019).

MA 27.2 Tue 14:15 HSZ 02

Strain-dependent electronic reconstruction in Sr_2CoIrO_6 double perovskite from DFT+U+SOC calculations — •Jiongyao Wu and Rossitza Pentcheva — Department of Physics and Center for Nanointegration (CENIDE) Universitat Duisburg-Essen, Duisburg, Germany

The double perovskite Sr_2CoIrO_6 (SCIO) can be regarded as a (111)-superlattice of alternating $SrIrO_3$ (SIO) and $SrCoO_3$ (SCO) layers. Here we explore the electronic and magnetic properties in the framework of density functional theory (DFT) including a Hubbard U term and spin-orbit coupling (SOC) with the PBEsol exchange correlation functional. While the end member SIO is metallic with a quenched spin and orbital moment and bulk SCO is a G-type antiferromagnetic (AFM) insulator with spin and orbtial moment of 2.7 and 0.26 μ_B, respectively, the double perovskite SCIO emerges as an AFM Mott insulator with a band gap of $\sim$ 500 - 600 meV. Additionally, Ir acquires a spin moment of 1.5 μ_B pointing towards a $j = 1/2$ Mott insulating state in SCIO, similar to other iridates. Analysis of the orbital occupation indicates substantial charge transfer from the Ir to the Co ion. Moreover, subtle changes in orbital occupation are observed as the strain is varied from compressive (a_{NdGaO_3}) to tensile (a_{SrTiO_3}).

We acknowledge funding by the German Science Foundation within CRC/TRR80, project G3.

MA 27.3 Tue 14:30 HSZ 02

Sensitivity of non-local fluctuations on surface effects in ultra-thin $SrVO_3$ films — •Matthias Pickem, Jan M. Tomczak, and Karsten Held — Institute of Solid State Physics, TU Wien, Austria

Recent experiments show that strong electronic correlations cause the conventional Fermi-liquid state of bulk $SrVO_3$ to be destroyed in films below a critical thickness. However new experimental results challenge the current understanding of the details of this breakdown.

To this end we perform realistic density functional theory (DFT) + dynamical mean-field theory (DMFT) calculations of $SrVO_3$ on $SrTiO_3$ substrate. Depending on the simulated interface ($SrVO_3$ termination, surface reconstructions, or additional $SrTiO_3$ capping) we find that different mechanism cause this aforementioned break-down of the Fermi-liquid state.

Furthermore, calculations on the two-particle level (DMFT susceptibilities) reveal that the different interfaces result in vastly different instabilities.

MA 27.4 Tue 14:45 HSZ 02

Planar GHz resonators on $SrTiO_3$: Suppressed losses at temperatures below 1 K — Vincent T. Engl, Nikolaj G. Ebensperger, Lars Wendel, and •Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany

The complex dielectric constant $\hat{\epsilon} = \epsilon_1 + i\epsilon_2$ of $SrTiO_3$ reaches high values $\epsilon_1 \approx 2 * 10^4$ at cryogenic temperatures, while the dielectric losses (ϵ_2) are much stronger than for other crystalline dielectrics. $SrTiO_3$ is a common substrate for oxide thin films, like the superconducting $LaAlO_3/SrTiO_3$ system, but the large ϵ_1 and ϵ_2 restrict high-frequency quantum devices on $SrTiO_3$. Here we present superconducting coplanar Nb resonators on $SrTiO_3$, which we successfully operate in a distant-flip-chip geometry [1] at frequencies that exceed 1 GHz. We find a pronounced and unexpected increase in resonator quality factor Q at temperatures below 1 K, reaching up to $Q \approx 800$. We attribute this to substantial changes of the dielectric losses in $SrTiO_3$ at mK temperatures, and we also detect non-monotonous changes in the temperature-dependent ϵ_1. These findings [2] challenge our present understanding of the dielectric properties of $SrTiO_3$ and at the same time demonstrate that cryogenic high-frequency devices on $SrTiO_3$ are more feasible than previously assumed.

[1] L. Wendel *et al.* arXiv:1911.10518 [cond-mat.supr-con]
[2] V. T. Engl *et al.* arXiv:1911.11456 [cond-mat.supr-con]

MA 27.5 Tue 15:00 HSZ 02

Tuning superconductivity at the $Al_2O_3/SrTiO_3$-interface with light — •Daniel Arnold, Dirk Fuchs, and Roland Schäfer — Institute for Solid State Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

The 2-DEG at $SrTiO_3$-based interfaces is sensitive to illumination with visible light [1], which at low temperatures can be used to tune the transition temperature of the superconducting state in a nonvolatile manner [2]. We present studies on an $Al_2O_3/SrTiO_3$ sample with micro bridges running along different crystallographic directions at the interface. We are able to tune the low temperature conductance by illuminating the sample and reverse the altered state by thermal treatment at low temperatures ($T < 15$ K). Transport measurements in dependence of the magnetic field and temperature are conducted in different states, characterized by the tunable but time independent resistance at 1 K. The Berezinskii-Kosterlitz-Thouless transition in this system can be addressed by the current voltage behavior, which simultaneously gives further information on the inhomogeneous nature of the superconducting phase.

[1] M. Yazdi-Rizi et al., PRB 95 (2017)
[2] D. Arnold et al., APL 115 (2019)

MA 27.6 Tue 15:15 HSZ 02

Crystalline anisotropy of magnetoresistance in LAO/STO nanostructures — •Mithun Sheena Prasad[1] and Georg Schmidt[1,2] — [1].Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, D-06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Meterialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4, D-06120 Halle, Germany

The high-mobility two-dimensional electron gas (2DEG) confined at the interface $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) provides new opportunities to explore Nano electronic devices. In our group we have developed an industry compatible Nano patterning technique [1] for the

LAO/STO interface. Recent studies on this interface have revealed that at low temperature the current is confined to filaments which are linked to structural domain walls in the STO with drastic consequences for example for the temperature dependence of local transport properties. We have investigated magneto-transport in nanostructures having different orientation with respect to the lattice. Our experiments show that not only the resistance but also the magnetoresistance varies with orientation. The magnetoresistance can even change sign for different orientations and again this can change after a warm-up cool-down cycle strongly supporting the model of filamentary charge transport.
[1] M. Z. Minhas, H. H. Blaschek, F. Heyroth, and G. Schmidt, AIP Advances 6, 035002 (2016)

MA 27.7 Tue 15:30 HSZ 02

Study of 2D superconductivity at oxide interfaces by microwave resonators — •Edouard Lesne[1], Yildiz Saglam[1], Daniel Bothner[1], Felix Schmidt[1], Marc Gabay[2], Gary Steele[1], and Andrea Caviglia[1] — [1]Delft University of Technology — [2]Université Paris-Saclay

The emergent two-dimensional electron system (2DES) formed at the interface between LaAlO3 (LAO) and SrTiO3 (STO) insulating oxides has been a subject of great interest in condensed matter physics during the last decade. Recently, (111)-oriented LAO/STO interfaces have been shown to exhibit an electronic correlation driven reconstruction of its band structure and a two-dimensional superconducting (SC) ground state, both tunable by electrostatic field-effect.

Superconducting coplanar waveguide (SCPW) resonators are tools of exquisite sensitivity for probing low energy excitations in quantum materials, due to their intrinsic low ohmic losses and high quality factors, highly relevant to quantum technology platforms. Here, in order to study the superconducting state at the LAO/STO(111) interface, we designed embedded SCPW resonators whose microwave resonance frequency can be tuned by electrostatic gating, manifesting a change of the 2DES superfluid density through a large change of its kinetic inductance. This allows us to map the SC phase diagram in a detection scheme that goes beyond traditional resistive measurements. Our work highlights the potential of such an approach to the fundamental study of superconductivity in complex materials.

MA 28: Frustrated Magnets - Spin Liquids 2 (joint session TT/MA)

Time: Tuesday 14:00–15:15 Location: HSZ 304

MA 28.1 Tue 14:00 HSZ 304

Theory of partial quantum disorder in the stuffed honeycomb Heisenberg antiferromagnet — •Urban F. P. Seifert and Matthias Vojta — Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

Recent numerical results [Gonzalez *et al.*, Phys. Rev. Lett. **122**, 017201 (2019); Shimada *et al.*, J. Phys. Conf. Ser. **969**, 012126 (2018)] point to the existence of a partial-disorder ground state for a spin-1/2 antiferromagnet on the stuffed honeycomb lattice, with 2/3 of the local moments ordering in an antiferromagnetic Néel pattern, while the remaining 1/3 of the sites display short-range correlations only, akin to a quantum spin liquid.

In this talk, we derive an effective model for this disordered subsystem, by integrating out fluctuations of the ordered local moments, which yield couplings in a formal $1/S$ expansion, with S being the spin amplitude. The result is an effective triangular-lattice XXZ model, with planar ferromagnetic order for large S and a stripe-ordered Ising ground state for small S, resulting from frustrated Ising interactions. Within semiclassical analysis, the transition point between the two orders is located at $S_c = 0.646$, being very close to the relevant case $S = 1/2$. Near $S = S_c$ quantum fluctuations tend to destabilize magnetic order. We conjecture that this applies to $S = 1/2$, thus explaining the observed partial-disorder state.

MA 28.2 Tue 14:15 HSZ 304

Dirac Spin Liquid on the Spin-1/2 Triangular Heisenberg Antiferromagnet — •Shijie Hu[1], Wei Zhu[2], Sebastian Eggert[1], and Yin-Chen He[3] — [1]Physik und OPTIMAS, Technische Universität Kaiserslautern — [2]Natural Sciences, Westlake Institute of Advanced Study, Hangzhou — [3]Perimeter Institute, Waterloo

We study the spin liquid candidate of the spin-1/2 J_1-J_2 Heisenberg antiferromagnet on the triangular lattice by means of density matrix renormalization group (DMRG) simulations. By applying an external Aharonov-Bohm flux insertion in an infinitely long cylinder, we find unambiguous evidence for gapless U(1) Dirac spin liquid behavior. The flux insertion overcomes the finite size restriction for energy gaps and clearly shows gapless behavior at the expected wave-vectors. Using the DMRG transfer matrix, the low-lying excitation spectrum can be extracted, which shows characteristic Dirac cone structures of both spinon-bilinear and monopole excitations. Finally, we confirm that the entanglement entropy follows the predicted universal response under the flux insertion [1].
[1] Phys. Rev. Lett. **123**, 207203 (2019).

MA 28.3 Tue 14:30 HSZ 304

Phonon attenuation in $\mathbb{Z}_2$ quantum spin liquids — •Johannes Lang[1], Francesco Piazza[1], Roderich Moessner[1], and Matthias Punk[2] — [1]Max-Planck Institut für Physik komplexer Systeme, Dresden, Deutschland — [2]Ludwig-Maximilians-Universität München, München, Deutschland

In $\mathbb{Z}_2$ quantum spin liquids low lying excitations in the form of visons can couple to lattice vibrations. The high degree of frustration in the spin lattice results in an enlarged unit cell for the visons, which in turn has characteristic signatures in phonon attenuation.

MA 28.4 Tue 14:45 HSZ 304

Rank-2 Coulomb Spin Liquids from Classical Spins — •Owen Benton[1], Han Yan[2], Ludovic Jaubert[3], and Nic Shannon[2] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Okinawa Institute of Science and Technology Graduate University — [3]CNRS Bordeaux

Coulomb spin liquids are well studied spin liquid states exhibiting emergent electromagnetism, having a coarse-grained description corresponding to Maxwell's laws. It has recently been appreciated that even more exotic scenarios are possible, realizing generalizations of electromagnetism with rank-2 electric and magnetic fields. These are of particular interest since the emergent charges of the rank-2 electromagnetism can be fractons, with fundamentally constrained mobility.

In this talk I will describe an approach to finding simple, bilinear models, for classical spins which realize rank-2 Coulomb phases at low temperature. Such models provide access to rank-2 Coulomb phase physics in a setting amenable to efficient numerical study and also suggest directions to look for rank-2 Coulomb phases in experiment.

Remarkably, we find that a traceless, vector-charged, rank-2 Coulomb phase can be generated by perturbing a simple Heisenberg model on the pyrochlore lattice with breathing anisotropy and weak Dzyaloshinskii-Moriya interactions. This enables us to identify Yb-based breathing pyrochlores as potential candidate systems and to make explicit predictions for how the rank-2 Coulomb phase would manifest itself in experiment.

MA 28.5 Tue 15:00 HSZ 304

Single-site magnetic anisotropy governed by interlayer cation charge imbalance in triangular-lattice $AYbX_2$ — •Ziba Zangenehpourzadeh, Stanislav Avdoshenko, Jeroen van den Brink, and Liviu Hozoi — IFW Dresden, 01069 Dresden, Germany

The behavior in magnetic field of a paramagnetic center is characterized by its g tensor. Here we shed light on the anisotropy of the g tensor of Yb^{3+} $4f^{13}$ ions in $NaYbX_2$ and $NaYbO_2$, layered triangular-lattice materials suggested to host spin-liquid ground states. Using quantum chemical calculations we show that, even if the ligand-cage trigonal distortions are significant in these systems, the decisive role in realizing strongly anisotropic, g factors is played by interlayer cation charge imbalance effects. The latter refer to the asymmetry experienced by a given Yb center due to having higher ionic charges at adjacent metal sites within the magnetic ab layer. This should be a rather general feature of $4f^{13}$ layered delafossites: less interlayer positive charge is associated with stronger in-plane magnetic response [1].
[1] Z. Zangeneh, et al, Phys. Rev. B **100**, 174436 (2019).

MA 29: Focus Session: Magnon Polarons – Magnon-Phonon Coupling and Spin Transport (joint session MA/HL)

The coupling of spin waves and atomic lattice vibrations in solid magnetic states, so-called magnon polarons (MPs), can have large impact on spin transport properties as recently explored for spin-Seebeck effect, spin pumping and nonlocal spin transport. This resonant enhancement can be reached when the magnon dispersion is shifted by a magnetic field and crosses the phonon dispersion with sufficient overlap. While initially observed at low temperatures and large magnetic fields, further material and device developments have led to MPs at room temperature and moderate magnetic fields. Thus, MPs become important for the manipulation and amplification of spin currents in spintronic and spin caloritronic devices, e.g. by carrying the spins much further than using uncoupled magnons. This focus session highlights the main important research outcomes for MPs, state-of-the-art techniques to detect MPs, such as Brillouin light scattering and neutron scattering, and to study MP transport, e.g. by spin Seebeck effect and nonlocal spin transport, as well as the investigation of MPsin different material classes such as garnets, ferrites and antiferromagnets. In addition, the excessive theoretical work on MPs performed recently is addressed in this focus session.

Organizer: Timo Kuschel (Bielefeld University)

Time: Wednesday 9:30–13:00 Location: HSZ 04

Invited Talk MA 29.1 Wed 9:30 HSZ 04
Magnon-polaron transport in magnetic insulators — •Benedetta Flebus — University of Texas at Austin, Austin, USA

In this talk, I will introduce the anomalous features in the magnetic field and temperature dependence of the spin Seebeck effect observed by Kikkawa et al. [PRL 117, 207203 (2016)] and explain how they can be interpreted as a signature of magnon-polaron transport.

Specifically, I will discuss how magnetoelastic coupling between magnetic moments and lattice vibrations in ferromagnets can gives rise to magnon-polarons, i.e., hybridized magnon and phonon modes. I will derive a Boltzmann transport theory for the mixed magnon-phonon modes and show that magnon-polaron formation can lead to transport anomalies when the disorder scattering in the magnetic and elastic subsystems is sufficiently different.

Invited Talk MA 29.2 Wed 10:00 HSZ 04
Spin-phonon coupling in non-local spin transport through magnetic insulators — •Rembert Duine — Institute for Theoretical Physics, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands — Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Long-range spin transport through ferromagnetic and antiferromagnetic insulators has recently been demonstrated. In this talk I will discuss how spin-phonon interactions influence this transport. In the first part of the talk I will discuss how bulk spin-phonon interactions lead to magnon-polaron formation and how this composite boson influences the non-local transport. In the second part, I will discuss how spin-phonon interactions across an interface give rise to long-distance spin transport that is carried purely by phonons.

Invited Talk MA 29.3 Wed 10:30 HSZ 04
Anisotropic transport of spontaneously accumulated magneto-elastic bosons in yttrium iron garnet films — •Alexander A. Serga — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaisersalutern, Germany

It is well known that bosonic quasiparticles as excitons, polaritons or magnons are able to spontaneously form Bose-Einstein condensates (BECs). However, interactions between quasiparticles of a different nature, for example, between magnons and phonons, can significantly alter their properties and, thus, modify the condensation scenarios.

Here, I present a novel condensation phenomenon mediated by the magnon-phonon interaction: a bottleneck accumulation of hybrid magneto-elastic bosons—magnon polarons. Similar to the magnon BEC, the phenomenon is observed in a microwave-driven single-crystal ferrimagnetic film. However, unlike BEC, which is a consequence of equilibrium Bose statistics, the bottleneck accumulation is determined by varying interparticle interactions. Furthermore, the accumulated quasiparticles possess a nonzero group velocity. Our recent 2D transport measurements show the simultaneous formation of a few distinct magnon-polaron groups, which propagate in film plane as spatially localized beams with different group velocities. The role of the magnetoelastic anisotropy in the beam formation and interaction of the accumulated quasiparticles with the magnon BEC are discussed.

Financial support of this work by the European Research Council Advanced Grant “SuperMagnonics” is gratefully acknowledged.

MA 29.4 Wed 11:00 HSZ 04
Formation of magnon polarons in ferromagnetic nanogratings — •Felix Godejohann[1], Alexey Scherbakov[1,2], Serhii Kukhtaruk[1,3], Alexander Poddubny[2], Dmytro Yaremkevych[1], Mu Wang[5], Achim Nadzeyka[4], Dmitri Yakovlev[1,2], Andrew Rushforth[5], Andrey Akimov[5], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany. — [2]Ioffe Inst., RAS, St. Petersburg, Russia — [3]Dept. of Theo. Phys., V.E. Lashkaryov Inst. of Semiconductor Phys., Kyiv, Ukraine — [4]Raith GmbH, 44263 Dortmund, Germany — [5]School of Phys. and Astronomy, Univ. of Nottingham, UK

In our time-resolved experiments with ferromagnetic nanogratings (NGs), the formation of coherent magnon polarons is confirmed by direct evidence of the avoided crossing effect, as well as by several bright indirect manifestations. The NGs have been produced by focused ion beam milling into a 105 nm-thick $Fe_{0.81}Ga_{0.19}$ film. They have a lateral period of 200 nm and consist of parallel grooves of 100-nm width and 7-21 nm depth milled along the [100]-crystallographic direction. We perform transient magneto-optical measurements in a conventional pump-probe scheme with micron spatial resolution, where the femtosecond pump pulse excites the NGs, while the probe pulse serves to detect coherent lattice and magnetic responses. Using an external magnetic field, the magnon modes can be brought into resonance with the localized phonon modes of the NG resulting in the formation of magnon polarons, where the coupling strength is determined by the spatial overlap of the interacting modes.

Invited Talk MA 29.5 Wed 11:15 HSZ 04
Boltzmann approach to the longitudinal spin Seebeck effect — Piet Brouwer and •Rico Schmidt — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

We develop a Boltzmann transport theory of coupled magnon-phonon transport in ferromagnetic insulators. The explicit treatment of the magnon-phonon coupling within the Boltzmann approach allows us to calculate the low-temperature magnetic-field dependence of the spin-Seebeck voltage. We consider both a high-temperature regime, in which magnon and phonon branches are coupled incoherently, and a low-temperature regime, which has strongly coupled magnon-polaron excitations. For the magnetic field dependence of the spin Seebeck voltage in both limits we observe similar features as found by Flebus et al. [Phys. Rev. B 95, 144420 (2017)] for a strongly coupled magnon phonon system that forms magnon-polarons, consistent with experimental findings in yttrium iron garnet by Kikkawa et al. [Phys. Rev. Lett. 117, 207203 (2016)].

Invited Talk MA 29.6 Wed 11:45 HSZ 04

Magnon-polaron excitations in the noncollinear antiferromagnet Mn_3Ge — •Aleksandr Sukhanov — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

In this talk, the detailed inelastic neutron scattering measurements of the noncollinear antiferromagnet Mn_3Ge will be discussed. Time-of-flight and triple-axis spectroscopy experiments showed that the magnetic excitations in Mn_3Ge have a 5-meV gap and display an anisotropic dispersive mode reaching $\simeq$ 90 meV at the boundaries of the magnetic Brillouin zone. The spectrum at the zone center shows two additional excitations that demonstrate characteristics of both magnons and phonons. The *ab initio* lattice-dynamics calculations show that these can be associated with the magnon-polaron modes resulting from the hybridization of the spin fluctuations and the low-energy optical phonons. The observed magnetoelastic coupling agrees with the previously found negative thermal expansion in this compound and resembles the features reported in the spectroscopic studies of other antiferromagnets with the similar noncollinear spin structures.

Invited Talk MA 29.7 Wed 12:15 HSZ 04

Magnon-Polarons in different flavors: (anti)ferromagnetic to topological — •Akashdeep Kamra — Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway

Due to magnetoelastic coupling, magnons and phonons in a magnetic material can combine to form hybrid quasiparticles, inheriting properties from both, called magnon-polarons. In this talk, we will examine and clarify the essential requirements for their hybridization in terms of the typical conservation laws and the nature of the magnetoelastic coupling. This will allow us to deduce the properties, such as spin, of the magnon-polarons thus formed by examining the general symmetries of the material and excitation propagation direction. In carrying out this general discussion, we will refer to the cases of magnon-polarons in ferromagnets as examples. What is their spin? What kind of phonons can the magnons hybridize with? Then, we will apply the general principles developed to the cases of antiferromagnets and topological magnonic insulators thereby demonstrating magnon-polarons with novel, tunable, and chiral properties. We will conclude the discussion with an outlook on some open questions and possible future avenues in this context.

References: [1] A. Kamra, H. Keshtgar, P. Yan, and G. E. W. Bauer. Phys. Rev. B 91, 104409 (2015). [2] H. T. Simensen, R. E. Troncoso, A. Kamra, and A. Brataas. Phys. Rev. B 99, 064421 (2019). [3] E. Thingstad, A. Kamra, A. Brataas, and A. Sudbø. Phys. Rev. Lett. 122, 107201 (2019).

MA 29.8 Wed 12:45 HSZ 04

Topological Magnon-Phonon Hybrid Excitations in Two-Dimensional Ferromagnets with Tunable Chern Numbers — •Gyungchoon Go[1], Se Kwon Kim[2], and Kyung-Jin Lee[1,3] — [1]Department of Materials Science and Engineering, Korea University, Seoul 02841, Korea — [2]Department of Physics and Astronomy, University of Missouri, Columbia, Missouri 65211, USA — [3]KU-KIST Graduate School of Converging Science and Technology, Korea University, Seoul 02841, Korea

We theoretically investigate magnon-phonon hybrid excitations in two-dimensional ferromagnets. The bulk bands of hybrid excitations, which are referred to as magnon polarons, are analytically shown to be topologically nontrivial, possessing finite Chern numbers. We also show that the Chern numbers of magnon-polaron bands and the number of band-crossing lines can be manipulated by an effective magnetic field. For experiments, we propose to use the thermal Hall conductivity as a probe of the finite Berry curvatures of magnon-polarons. Our results show that a simple ferromagnet on a square lattice supports topologically nontrivial magnon polarons, generalizing topological excitations in conventional magnetic systems.

MA 30: Ultrafast Magnetization III

Time: Wednesday 9:30–12:45 Location: HSZ 101

MA 30.1 Wed 9:30 HSZ 101

Conical Mirror XUV Polarimeter for complete ultrafast magnetic sampling at M- edges of Fe, Co & Ni — •Christian Strüber[1,2], Bertram Friedrich[1], Felix Willems[1], Piet Hessing[1], Kelvin Yao[1], Wolfgang Dietrich Engel[1], Daniel Schick[1], Bastian Pfau[1], Clemens von Korff Schmising[1], and Stefan Eisebitt[1,3] — [1]Max-Born-Institut, Berlin — [2]Freie Universität Berlin — [3]Technische Universität Berlin

Transient XUV absorption spectroscopy at 3p to 3d transitions (M-edges) probes changes to the magnetic dichroism initiated by a visible/NIR pump pulse. In a complementary technique the Faraday rotation of linear XUV pulses transmitted through thin magnetic layers is observed with an XUV polarization analyzer. In current setups the polarization detector needs to be rotated slowing down acquisition. We present a conical mirror XUV (COMIX) polarimeter for ultrafast magnetic investigations that access the full complex dichroic index of refraction. Due to the rotational symmetry of the device the COMIX polarimeter samples all rotation angles simultaneously. By observing the magnetically dependent changes in ellipticity $\Delta\epsilon$ and orientation $\Delta\theta$ of the polarization state after transmitting through thin magnetic samples the full complex magneto-optical functions are measured. In a first demonstration of the COMIX polarimeter's capabilities, we compare Faraday measurements at FeGd samples performed at synchrotron and HHG sources.

MA 30.2 Wed 9:45 HSZ 101

A novel high flux XUV light source for the study of ultrafast element-specific magnetization dynamics — •Christina Möller, Johannes Otto, Henrike Probst, Mariana Brede, Matthijs Jansen, Sabine Steil, Daniel Steil, and Stefan Mathias — 1. Physikalisches Institut, Göttingen, Germany

In recent years, it has been shown that the combination of a femtosecond extreme ultraviolet (XUV) light source with magneto-optical Kerr measurements (MOKE) provides a powerful tool for the study of element-specific magnetization dynamics. Using a high-harmonic based XUV MOKE setup, it was for instance found that femtosecond spin currents drive ultrafast magnetic processes [1], how magnetic sublattices interact on femtosecond timescales [2], and that spin dynamics can be induced coherently and directly on the timescale of the optical excitation itself [3,4].

Here, we present our new element-specific HHG based MOKE experiment, which makes use of a high-repetition rate fiber-based laser amplifier system, and adds high magnetic fields and cooling capabilities to the control of the magnetic sample, thereby overcoming limitations of the first harmonic generation (HHG) based MOKE setups. We show first element-specific data of a Fe/Ni alloy and manganite films highlighting the improved signal quality of the setup.

[1] Rudolf et al., Nature Comm. 3, 1037 (2012).
[2] Mathias et al., PNAS 108, 4792 (2012).
[3] Hofherr et al., Science Advances, in press (2019).
[4] Siegrist et al., Nature 571, 240 (2019).

MA 30.3 Wed 10:00 HSZ 101

Separating spin and orbital magnetic dynamics via time-resolved x-ray absorption — •N. Thielemann-Kühn[1], T. Amrhein[1], W. Bronsch[1], S. Jana[2], N. Pontius[2], C. Schüssler-Langeheine[2], R. Engel[3], P. Miedema[3], M. Beye[3], B. van Kuiken[4], A. Scherz[4], R. Carley[4], L. Le Guyader[4], N. Agarwal[4], L. Mercadier[4], G. Mercurio[4], M. Teichmann[4], A. Yaroslavtsev[4], and M. Weinelt[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Alberteinsteinstr. 15, 12489 Berlin — [3]Deutsches Elektronen Synchrotron DESY, Notkestraße 85, 22607 Hamburg — [4]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld

We study ultrafast spin and orbital momenta dynamics by recording highly energy-resolved 3d-4f absorption spectra. After optical excitation we identify changes in L and S via the multiplet structure. Due to the strong localization of the 4f states the absorption spectra of rare earth metals can be described by atomic calculation of their trivalent ions. At the European XFEL we preformed pump-probe X-ray absorption spectroscopy for the RE-metals Tb and Gd, at the 3d-4f absorption edge. We find that only for Tb we excite multiplet components with the pump laser. This implies transient decoupling of L and

S, for which we observe a time-dependence that follows the 5d6s hot electron distribution. We conclude that scattering with the optically excited 5d6s valence electrons leads to excitation of the 4f multiplet components.

MA 30.4 Wed 10:15 HSZ 101

Characterization of high harmonics spectra generated by the 1.3TW /1 kHz JuSPARC laser system in different gas targets — •Christian Greb[1], Roman Adam[1], Sarah Heidtfeld[1], Fangzhou Wang[1], Derang Cao[1,2], Markus Büscher[1], and Claus M. Schneider[1] — [1]Forschungszentrum Jülich, Peter Grünberg Institute, 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China

High harmonic generation (HHG) is a well-established technique for generation of spatially and temporal coherent light pulses from the EUV to soft x-ray region (20 eV - 300 eV). The maximum achievable photon energy (HHG cut-off) can be increased by employing higher intensity and longer wavelength of the fundamental laser light [1]. For our experiments, intended to elucitdate spin and charge dynamics in complex materials, we recently commissioned a new Ti:Sapphire based laser system ($\lambda \sim 800$nm) capable of generating pulse energies up to 38 mJ at a pulse duration of 30 fs (peak power 1.3 TW) and a repetition rate of 1 kHz. In our first experiments, we demonstrate that we can control the HHG process by varying laser intensity, gas pressure and elemental composition, pulse duration, laser focus and and by tuning the gas-target position. In the next step we enhance the maximum HHG energy by tuning the wavelength of the fundamental driving light by employing optical parametric amplification. Our experimental studies provide further insight into the process of high harmonic generation at high peak intensities.

[1] T. Popmintchev et al., Science 336, 6086 (2012)

MA 30.5 Wed 10:30 HSZ 101

Probing strain as a proxy for magnetic ordering in a rare earth metal — •Alexander von Reppert[1], Maximilian Mattern[1], Jan-Etienne Pudell[1], Steffen Zeuschner[1,2], Karine Dumesnil[3], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut Jean Lamour (UMR CNRS 7198), Université Lorraine, Nancy, France

Optical excitation of spin-ordered rare earths triggers a complex response of the crystal lattice, since expansive stresses from electron and phonon excitations compete with a sizable contractive stress induced by spin disorder. Using ultrafast X-ray diffraction experiments we study the layer specific strain response of a Dysprosium film adjacent to a non-magnetic detection layer upon fs laser-excitation. Both the picosecond strain pulse and the thermal transport show signatures of a sizable energy transfer to magnetic excitations in the rare earth. The modeled rise times of the magnetic stress are in close agreement with the recently reported demagnetization timescales, which shows that the strain response can serve as a proxy for the time-dependent magnetic ordering in both antiferromagnetic and ferromagnetic rare earths. We experimentally corroborate this finding using a two-pulse excitation scheme, wherein the first laser pulse changes the magnetic state, while the second pump pulse triggers a lattice response that strongly depends on the degree of disorder of the spin system.

MA 30.6 Wed 10:45 HSZ 101

Ultrafast Control of Charge Density and Spin Density waves in Chromium — •Louis Ponet[1,2], Oleg Gorobtsov[3], Andrej Singer[3], and Sergey Artyukhin[1] — [1]Istituto Italiano di Tecnologia — [2]Scuola Normale Superiore di Pisa — [3]Cornell University, Ithaca

Experimental advances in ultrafast physics have allowed to monitor structural and electronic processes and even phase transitions on their natural timescales. Here we model recent experiments on ultrafast control of spin density wave phase in elemental Chromium with a sequence of optical pulses. The strain wave and CDW, induced by the spin density modulation via exchange striction, are monitored using x-ray diffraction. Results show order parameter oscillations and a partial melting of the SDW in response to optical pulses. Interestingly, depending on the exact delay between two sequential optical pulses, one can increase or decrease the oscillation amplitude, allowing for optimal control. We use Landau theory and heat transfer equations to describe the dynamics of the interacting charge and spin density waves. All details of the experiment are replicated to a high degree by the model.

15 min. break.

MA 30.7 Wed 11:15 HSZ 101

Mutual influence of relaxation processes in exchange coupled magnetic alloys — •Sebastian T. Weber and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern,

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale. The laser-pulse drives the electrons out of equilibrium, which starts a chain reaction of different relaxation processes.
We reveal the different mechanism responsible for the magnetization dynamics and their interplay. We have set up a model [1] to trace the spin-resolved electron dynamics in dependence on different states of the magnetization process. So far, the model needed multiple phenomenological parameters. In this talk, we present our approach to reduce the amount of those parameters.

[1] B. Y. Mueller und B. Rethfeld, Phys. Rev. B 90, 144420 (2014)

MA 30.8 Wed 11:30 HSZ 101

Microscopic theory for the real-time magnetization dynamics in bilayers driven by ultrafast laser pulses — •Hanan Hamamera, Filipe Souza Mendes Guimaraes, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Spintronic, magnetic and optical properties of different materials can be manipulated by ultrashort laser pulses [1,2]. Here we present our recently-developed method to investigate ultrafast spin dynamics: Employing a realistic tight-binding Hamiltonian parametrized from first-principles electronic structure calculations, we directly solve for the real-time evolution of the electronic state of a chosen system. We apply this method to different metallic bilayers, such as Fe/W(110) and Co/Pt(001), focusing on how the magnetization dynamics is influenced by its initial orientation and how it relates to the polarization of the driving laser pulse. We also investigate whether a pumping protocol involving a second laser pulse may lead to improved switching, inspired by the experiments of Ref. [3].
This work was supported by the Palestinian-German Science Bridge BMBF program and the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).
[1] T. Seifert *et al.*, Nature Photon. **10**, 483-488 (2016)
[2] J. Chen *et al.*, Phys. Rev. Lett. **122**, 067202 (2019)
[3] K. T. Yamada *et al.*, arXiv:1903.01941 (2019)

MA 30.9 Wed 11:45 HSZ 101

A real-space tight-binding approach to model ultrafast spin dynamics in heterostructures — •Franziska Töpler[1], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

In the process of laser-induced ultrafast demagnetization hot spin-polarized electrons are excited. In a system with a magnetic/nonmagnetic interface they generate a spin current crossing this interface. Various origins of this spin current generation are discussed in literature, for example the spin-dependent Seebeck effect [1] or energy- and spin-dependent electron transmittance of the interface [2].

To obtain a better understanding of the underlying microscopic processes and the role of the interface we implemented a real-space tight-binding model. We follow the temporal evolution of occupation numbers, including perturbation by laser excitation, by solving the corresponding equations of motion. Interaction with the phonon system is incorporated as the coupling to a bath in form of Lindblad operators. In addition link currents are defined as intersite occupation flow in analogy to conventional charge and spin currents. We investigate these in model systems composed of magnetic and nonmagnetic sites and compare our results to experimental findings.

[1] Seifert *et al.*, J. Phys. D: Appl. Phys. **51** (2018) 364003
[2] Alekhin *et al.*, J. Phys.: Condens. Matter **31** (2019) 124002

MA 30.10 Wed 12:00 HSZ 101

Macroscopic effects due to atomistic colored noise in magnetization dynamics — •Unai Atxitia[1] and Oksana Chubykalo-Fesenko[2] — [1]Fachbereich Physik, Freie Universitaet Berlin, 14195 Berlin, Germany — [2]Instituto de Ciencia de Materiales de Madrid,

CSIC, Cantoblanco, 28049 Madrid, Spain

The atomistic spin dynamics has recommended itself as a tool for modeling magnetization dynamics in the ultrafast timescale. This approach is based on the Langevin dynamics within the white noise approximation [1]. Here we investigate the macroscopic effects arising from the assumption that at the atomic level the noise is colored [2]. We derive analytically an equation of motion for the macrospin dynamics. We show that the colored noise assumption (i) introduces a red shift in the precession frequency which is temperature and correlation time dependent and (ii) slows down both transverse and longitudinal relaxation times. The increase of the transverse relaxation time effectively means the decrease of the so-called Gilbert damping. We compare the results with direct atomistic Langevin dynamics simulations using the colored noise approach [1]. For the transverse dynamics the effect of the colored noise becomes significant for the correlation times larger than 1 ps while for the longitudinal relaxation the effects are already visible for correlation times of the order of several femtoseconds (timescale of the precession in the exchange field). References: [1] R.F.L. Evans et al. J.Phys.:Cond.Matt 26, 103202 (2014) [2] U.Atxitia et al. Phys Rev.Lett. 102 057203 (2009).

MA 30.11 Wed 12:15 HSZ 101

Nonlocal Gilbert damping and magnetic interactions in noncollinear magnetic nanostructures from first principles — Sascha Brinker, •Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Damping is essential to the magnetization dynamics underpinning the performance of any type of magnetic device. Utilizing a first-principles description of the spin dynamics of noncollinear magnetic nanostructures based on linear-response time-dependent density functional theory [1], we demonstrate that the Gilbert damping and gyromagnetic tensors can be expressed in terms of couplings, chiral or not, of the magnetic moments. We illustrate the theory considering magnetic adatoms, dimers and trimers, both within a generalized Alexander-Anderson model and using real magnetic atoms on Au(111) together with magnetic constraints [2]. These properties are related to the filling of the magnetic orbitals of the clusters, to their hybridization with the surface electrons, and to the role played by spin-orbit coupling. We put forward a generalized Landau-Lifshitz-Gilbert equation accounting for the dependence of damping on the underlying magnetic structure and address the case of different magnetic ground states and their dynamics. — Work funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).

[1] M. dos Santos Dias *et al.*, Phys. Rev. B **91**, 075405 (2015)
[2] S. Brinker *et al.*, New J. Phys. **21**, 083015 (2019)

MA 30.12 Wed 12:30 HSZ 101

Ultrafast electrical signals generation using fs-laser pulses — •Bikash Das Mohapatra[1], Wolfgang Hoppe[1], Georg Woltersdorf[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, D-06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Meterialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4, D-06120 Halle, Germany

Electronics are getting faster and it would be relevant to get signals from electronic devices in THz regime. Several methods to generate THz electromagnetic pulses[1] have been researched where ultrafast transverse charge current is generated from spin current by the ISHE. We investigate the ultrafast electrical response from waveguide structures with thermocouples illuminated by fs laser pulses. This can give new insight into the study of thermopower in electronic structures to convert temperature differences into electrical signals in the THz regime. Waveguide structures are used with Au/Pt thermocouples which are fabricated using Sputter deposition and e-beam lithography. When fs-laser is pumped into one of two thermocouples, it leads to a difference in temperature resulting in ultrafast thermovoltage due to the Seebeck Coefficient S=-ΔV/ΔT. The voltages are measured using a 50 GHz sampling oscilloscope. An alternative route is pursued by demagnetizing DC biased GMR structures by fs pulses to use the breakdown in resistance for electrical pulse generation. [1] T. Kampfrath et al. ,"Femtosecond formation dynamics of the spin Seebeck effect revealed by terahertz spectroscopy", Nat. Comm. 9, 2899 (2018).

MA 31: Frustrated Magnets - Strong Spin-Orbit Coupling 1 (joint session TT/MA)

Time: Wednesday 9:30–13:00 Location: HSZ 304

Invited Talk MA 31.1 Wed 9:30 HSZ 304

Field-induced magnetic order in the Kitaev material α-RuCl$_3$ — •Lukas Janssen — Technische Universität Dresden, Dresden, Germany

α-RuCl$_3$ has recently been intensely debated in the context of a potential field-induced spin-liquid phase. However, interesting physics can be observed in this material also at field strengths below and above the putative spin-liquid regime. In this combined experimental and theoretical work, we demonstrate the existence of a novel ordered phase at intermediate field strengths, characterize its nature, and discuss implications for the dominant exchange interactions present in this material.

Talk includes results obtained with Christian Balz, Stephen E. Nagler, and Matthias Vojta.

MA 31.2 Wed 10:00 HSZ 304

Field-induced quantum phase transitions in α-RuCl$_3$ — •Sebastian Bachus[1], Yoshifumi Tokiwa[1], Vladimir Tsurkan[2], Alois Loidl[2], Anton Jesche[1], Alexander A. Tsirlin[1], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

Recently the observation of a half-integer quantized thermal Hall effect in the Kitaev material α-RuCl$_3$, possibly indicating chiral Majorana edge modes, attracted considerable attention [1]. It arises in a finite field range exceeding the critical field for long-range antiferromagnetic order. We utilize a high-resolution alternating field method for the precise determination of the truly adiabatic magnetocaloric effect or magnetic Grüneisen parameter down to ~ 1 K and in magnetic fields up to 15 T. Together with accompanying heat capacity measurements, it allows us to determine the entropy evolution when tuning the system into and out of the presumed topological Kitaev quantum spin liquid regime as a function of the applied field. We present a comprehensive analysis of the thermodynamic data and comparison to [2].

Work supported by the German Science Foundation via Project No. 107745057 (TRR80).

[1] Y. Kashara *et al.*, Nature 559, 227-231 (2018).
[2] C. Balz *et al.*, Phys. Rev. B 100, 060405(R) (2019).

MA 31.3 Wed 10:15 HSZ 304

High-Field Quantum Disordered State in α-RuCl$_3$ — •Anuja Sahasrabudhe[1], David Kaib[2], Stephan Reschke[3], Raphael German[1], Thomas Koethe[1], Jonathan Buhot[4], Dmytro Kamenskyi[4], Ciarán Hickey[5], Petra Becker[6], Vladimir Tsurkan[3,7], Alois Loidl[7], Seung-Hwan Do[8], Kwang-Yong Choi[8], Markus Grüninger[1], Stephen Winter[2], Zhe Wang[1,9], Roser Valentí[2], and Paul van Loosdrecht[1] — [1]Institute of Physics II, University of Cologne — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt — [3]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg — [4]High Field Magnet Laboratory (HFML - EMFL), Radbound University, Nijmegen — [5]Institute for Theoretical Physics, University of Cologne — [6]Institute for Geology and Mineralogy, University of Cologne — [7]Institute of Applied Physics, MD2028 Chisinau — [8]Department of Physics, Chung-Ang University, Seoul — [9]Institute of Radiation Physics, Helmholtz Zentrum Dresden-Rossendorf

Layered α-RuCl$_3$ does not show a true Kitaev quantum spin liquid state due to the presence of additional interactions leading to magnetic ordering at low temperature. This ordering can be suppressed by applying a moderate in-plane magnetic field, leading to a novel high field phase. Using Raman and THz spectroscopy, combined with an exact diagonalization study, we show that the induced high field state can be identified as a partially-polarized quantum disordered magnetic state characterised by a gapped multi-particle continuum out of which a bound-state emerges as well as a sharp single-particle response.

MA 31.4 Wed 10:30 HSZ 304

Pressure-dependent investigation of the elastic constants in α-$RuCl_3$ — •A. Hauspurg[1,2], S. Zherlitsyn[1], T. Yanagisawa[3], V. Felea[1], V. Tsurkan[4], K.-Y. Choi[5], S.-H. Do[5], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Department of Physics, Hokkaido University, Sapporo, Japan — [4]Institute of Physics, University of Augsburg, Germany — [5]Department of Physics, Chung-Ang University, Seoul, South Korea

As a paradigmatic example of the realization of Kitaev physics on a honeycomb lattice, α-$RuCl_3$ serves for numerous experimental investigations of fundamental physics of this model. Yet it shows a striped AF groundstate with evidence for a field-induced quantum spin liquid state. We performed investigations of the elastic constants by means of propagating ultrasound waves in this intriguing compound. Under variable magnetic fields, temperatures, and pressures we obtain further insight into its phase diagram. We will show evidence of pressure-dependent contributions of competing Kitaev and Heisenberg terms, which results in a suppression of the antiferromagnetically ordered phase at low temperatures.

MA 31.5 Wed 10:45 HSZ 304

Pressure-induced dimerization and Kitaev spin liquid regime of α-$RuCl_3$ — •Quirin Stahl[1], Gaston Garbarino[2], Tobias Ritschel[1], Francisco J. Martinez-Casado[3], Gilberto Fabbris[4], Joerg Strempfer[4], Maximilian Kusch[1], Anna Isaeva[1,5], Thomas Doert[5], Randirley Beltrán Rodríguez[6], Rajyavardhan Ray[6], Silvina P. Limandri[7], Maria Roslova[5], Liviu Hozoi[6], Ravi Yadav[6], Jeroen van den Brink[6,8], Gaël Bastien[6], Anja U.B. Wolter[6], Bernd Büchner[1,6], and Jochen Geck[1] — [1]IFMP, TU Dresden, Germany — [2]ESRF, Grenoble, France — [3]ILL, Grenoble, France — [4]APS, Argonne National Laboratory, USA — [5]Faculty of Chemistry and Food Chemistry, TU Dresden, Germany — [6]IFW Dresden, Germany — [7]IFEG, National University of Córdoba, Argentina — [8]Institute of Theoretical Physics, TU Dresden, Germany

Recently, the honeycomb material α-$RuCl_3$ has been identified as a possible realization of the Kitaev model, rendering this material an ideal platform for exploring Kitaev magnetism experimentally. However, the onset of long-range magnetic order at T_N= 7 K and ambient pressure, i.e. the absence of a spin liquid ground state, implies that α-$RuCl_3$ deviates from the ideal Kitaev model under these conditions. We therefore set out to elucidate whether α-$RuCl_3$ can be driven into the true Kitaev regime by means of hydrostatic pressure. Our x-ray diffraction and extended x-ray absorption fine structure studies reveal a rich structural phase diagram, including pressure induced Ru-Ru dimerization as well as a high-symmetry rhombohedral phase. The latter is indeed found to be very close to the ideal Kitaev model.

MA 31.6 Wed 11:00 HSZ 304

Giant coupling between phonons and Majorana fermions in a Kitaev spin liquid — •Dirk Wulferding[1,2], Youngsu Choi[3], Yann Gallais[4], Clément Faugeras[5], Peter Lemmens[1,2], Seung-Hwan Do[6], and Kwang-Yong Choi[3] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]Chung-Ang Univ., Seoul, Korea — [4]Univ. Paris-Diderot, Paris, France — [5]LNCMI Grenoble, France — [6]Oak Ridge National Lab, USA

In the Kitaev honeycomb candidate material α-$RuCl_3$ a continuum of fractionalized Majorana fermions exists which can be directly probed by Raman spectroscopy [1-5]. In-plane magnetic fields gap the continuum, thereby confining it energetically to the regime of optical phonons. Using high-field Raman spectroscopy [6], we shine a light onto the interplay of Majorana fermions and phonons, which results in a drastic reduction of the phonon lifetimes together with a renormalization of phonon energies.

Work supported by QUANOMET NL-4 and DFG LE967/16-1.

[1] Sandilands, et al., Phys. Rev. Lett. 114, 147201 (2014)
[2] Knolle, et al., Phys. Rev. Lett. 113, 187201 (2014)
[3] Glamazda, et al., Phys. Rev. B 95, 174429 (2017)
[4] Glamazda, et al., Nat. Commun. 7, 12286 (2016)
[5] Sahasrabudhe, et al., arXiv:1908.11617 (2019)
[6] Wulferding, et al., arXiv:1910.00800 (2019)

15 min. break.

MA 31.7 Wed 11:30 HSZ 304

Thermal Transport of the Kitaev spin-liquid candidate α-$RuCl_3$ — Richard Hentrich[1], •Matthias Gillig[1], Xiaochen Hong[1], Federico Caglieris[1], Maria Roslova[2], Anna Isaeva[1,2], Thomas Doert[2], Uli Zeitler[3], Matija Culo[3], Maryam Shahrokhvand[3], Bernd Büchner[1,4], and Christian Hess[1,4] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Germany — [2]Faculty of Chemistry and Food Chemistry, TU Dresden, Germany — [3]High Field Magnet Laboratory (HFML-EFML), Radboud University Nijmegen, 6525 ED Nijmegen, The Netherlands — [4]Center for Transport and Devices, TU Dresden, Germany

α-$RuCl_3$ currently is the best known candidate material for realizing Kitaev physics. Previous experiments on the longitudinal thermal conductivity revealed a strong coupling of he magnetic and phononic subsystems which results in a strongly magnetic field dependent thermal conductivity due to the field-induced opening of a gap [1]. Furthermore, a sizeable thermal Hall effect has been observed which triggered the search for signatures of fractionalized thermal transport due to topological edge modes near an in-plane field value of 8 T where long-range magnetic order is suppressed but the spin gap is still small [2]. Here we focus on low-temperature and high-field (up to 30 T) studies of the thermal transport which suggest the persistence of low-energy field-dependent modes up to the highest field studied at 30 T.

[1] R. Hentrich et al., Phys. Rev. Lett. **120**, 117240 (2018)
[2] Y. Kasahara et al., Nature **559**, 227 (2018)

MA 31.8 Wed 11:45 HSZ 304

Magnetic properties of two sodium ruthenates Na_2RuO_3 and Na_3RuO_4 — •Vera P. Bader[1], Alexander A. Tsirlin[1], Anton Jesche[1], Clemens Ritter[2], and Philipp Gegenwart[1] — [1]Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany — [2]Institut Laue-Langevin, Grenoble, France

Ruthenates show a diversity of magnetic phenomena, e.g. due to transitions between the non-magnetic $J = 0$ state and excited $J = 1$ levels in Ru^{4+} [1] or due to strong Ru-O covalency in the case of Ru^{5+} [2]. Powder samples of Na_2RuO_3 and Na_3RuO_4 were prepared via solid state reactions in a controlled atmosphere. The Ru^{4+} ions in Na_2RuO_3 form honeycomb layers which are stacked along the crystallographic c-axis. The measured diffraction pattern could be simulated under the assumption of stacking faults. The inverse susceptibility deviates from the Curie-Weiss behaviour and shows a downward bending in the high temperature region indicating a paramagnetic Van Vleck contribution which would be expected for a $J = 0$ ground state. In Na_3RuO_4 the Ru^{5+} ions form isolated tetramers which are composed of two equilateral triangles. The magnetic susceptibility reveals an antiferromagnetic transition at 30 K while the heat capacity data show two successive phase transitions at 25 K and 28 K. Up to now, the origin of the two phase transitions is not known. Neutron diffraction reveals the absence of symmetry lowering upon both transitions and the development of incommensurate magnetic order.

[1] J. Chaloupka et al., arXiv:1910.00074 (2019)
[2] A. Hariki et al., PRB 96 155135 (2017)

MA 31.9 Wed 12:00 HSZ 304

On the charge transfer energy in iridates: a HAXPES study — •Daisuke Takegami[1], Deepa Kasinathan[1], Klaus Wolff[1], Simone Altendorf[1], Chun-Fu Chang[1], Katharina Hoefer[1], Anna Meléndez-Sans[1], Yuki Utsumi[1], Federico Meneghin[1], Thai Duy Ha[1], Chien-Han Yen[1], Kai Chen[2], Chang-Yang Kuo[1,3], Yen-Fa Liao[3], Ku-Ding Tsuei[3], Ryan Morrow[4], Sabine Wurmehl[4], Beluvalli E. Prasad[1], Martin Jansen[5], Alexander Komarek[1], Philipp Hansmann[1], and Liu Hao Tjeng[1] — [1]MPI for Chemical Physics of Solids, Dresden, Germany — [2]Institute of Physics II, University of Cologne, Cologne, Germany — [3]National Synchrotron Radiation Research Center, Hsinchu, Taiwan — [4]Leibniz Institute for Solid State and Materials Research IFW Dresden, Dresden, Germany — [5]MPI for Solid State Research, Stuttgart, Germany

We have investigated the electronic structure of iridates in the double perovskite crystal structure containing either Ir^{4+} or Ir^{5+} using HAXPES. The experimental valence band spectra can be well reproduced using tight binding calculations including only the Ir 5d, O 2p and O 2s orbitals with parameters based on the down-folding of the DFT band structure results. We found that regardless the A and B cations, the A_2BIrO_6 iridates have essentially zero O 2p to Ir 5d charge transfer energies. They are extremely covalent systems with the consequence is that the magnetic exchange interactions become very long-ranged, thereby hampering the materialization of the Kitaev model. Nevertheless, it still would be possible to realize a spin-liquid system using the iridates with a proper tuning of the competing exchange interactions.

MA 31.10 Wed 12:15 HSZ 304

Magnetization density distribution of Sr_2IrO_4: Deviation from a *local* j_{eff} = 1/2 picture — Jaehong Jeong[1], •Benjamin Lenz[2,3], Arsen Gukasov[1], Xavier Fabreges[1], Andrew Sazonov[4], Vladimir Hutanu[4], Alex Louat[5], Cyril Martins[6], Silke Biermann[3,7], Veronique Brouet[5], Yvan Sidis[1], and Philippe Bourges[1] — [1]Laboratoire Léon Brillouin, CEA Saclay, Gif-sur-Yvette, France — [2]IMPMC, Sorbonne Université, Paris, France — [3]CPHT, Ecole Polytechnique, Palaiseau, France — [4]Institute of Crystallography, RWTH Aachen, Germany — [5]LPS, Université Paris-Saclay, Orsay, France — [6]LCPQ, Université Paul Sabatier, Toulouse, France — [7]Collège de France, Paris, France

5*d* iridium oxides are of huge interest due to the potential for new quantum states driven by strong spin-orbit coupling. The $j_{\mathrm{eff}} = 1/2$ state of Sr_2IrO_4 is such a state and consists of a quantum superposition of the three t_{2g} orbitals with nearly equal population, which stabilizes an unconventional Mott insulating state.
Here, we report an anisotropic and aspherical magnetization density distribution measured by polarized neutron diffraction in a magnetic field up to 5T at 4K, which strongly deviates from a *local* $j_{\mathrm{eff}} = 1/2$ picture. Theoretical considerations based on a momentum-dependent composition of the $j_{\mathrm{eff}} = 1/2$ orbital and an estimation of the different contributions to the magnetization density casts the applicability of an effective one-orbital $j_{\mathrm{eff}} = 1/2$ Hubbard model into doubt.
The analogy to the superconducting copper oxide systems might thus be weaker than commonly thought.

MA 31.11 Wed 12:30 HSZ 304

Magnetodielectric and magnetoelastic coupling in the frustrated fcc antiferromagnet $(NH_4)_2IrCl_6$ — •Nazir Khan and Alexander A. Tsirlin — Experimental Physics VI, University of Augsburg, 86135 Augsburg, Germany

Magnetodielectric and magnetoelastic phenomena in the fcc antifluorite $(NH_4)_2IrCl_6$ single crystal have been investigated using thermodynamic, dielectric and magnetostriction measurements. The compound is an antiferromagnetic Mott insulator with the charge gap Δ=0.9 eV and Néel temperature T_N=2.2 K. The antiferromagnetic ordering leads to a decrease in temperature-dependent dielectric constant at zero applied field. Further, in the magnetically ordered state the dielectric constant and macroscopic sample length show a strong magnetic field dependence. The dielectric constant increases monotonically with increasing field without any saturation up to a field 14 T where it exhibits a magnetocapacitance of about 0.6%. The magentodielectric phenomenon in the present system is believed to be due to the magnetostrictive effects and spin-phonon coupling. The magnetostrictive effects are evident from the temperature and field dependence of the macroscopic length change. Spin-phonon coupling results when the energy scale of a soft phonon mode associated with the rotation of $IrCl_6$ octahedra becomes comparable with that of a magnetic interaction or magnetic field.
[1] T. Katsufuji *et al.*, Phys. Rev. B **64**, 054415 (2001)
[2] Jaye K. Harada *et al.*, Phys. Rev. B **93**, 104404 (2016)

MA 31.12 Wed 12:45 HSZ 304

$MgIrO_3$ and $ZnIrO_3$: new hyperhoneycomb iridates — •Alexander O. Zubtsovskii and Alexander A. Tsirlin — EP VI, EKM, University of Augsburg, Germany

Iridates with edge-sharing IrO_6 octahedra host Kitaev interactions and show unusual magnetic behavior triggered by the exchange anisotropy and frustration. Here, we report two new compounds, $MgIrO_3$ and $ZnIrO_3$, obtained by the ionic substitution into the hyperhoneycomb beta-Li_2IrO_3. Crystal structures studied by synchrotron x-ray diffraction and high-resolution electron microscopy show lower symmetry than the parent compound, because Mg^{2+} and Zn^{2+} as divalent cations occupy different positions than Li^+. Magnetic behavior is characterized using magnetization and heat capacity measurements as well as muon spin relaxation.

MA 32: Multiferroics and Magnetoelectric Coupling I (joint session MA/KFM)

Time: Wednesday 9:30–12:15 Location: HSZ 401

MA 32.1 Wed 9:30 HSZ 401

High Temperature THz study of conical phase of BiFeO3 — •Dániel Gergely Farkas[1,2], Boglárka Tóth[1], Kirill Amelin[3], Toomas Rõõm[3], Urmas Nagel[3], Toshimitsu Ito[4], and Sándor Bordács[1] — [1]Department of Physics, Budapest University of Technology and Economics — [2]Condensed Matter Research Group of the Hungarian Academy of Sciences, 1111 Budapest, Hungary — [3]National Institute of Chemical Physics and Biophysics, Tallinn, Estonia — [4]National Institute of Advanced Industrial Science and Technology (AIST), Tokyo, Japan

Multiferroics, materials with coexisting ferroelectric and magnetic order, are one of the most intensively studied systems in modern solid-state physics. BiFeO3 is one of the most studied multiferroic material since its multiferroic phase persists also at room temperature [1].

A recent theoretical model [2] predicted a conical phase between the cycloidal and canted AFM phase in BiFeO3. Magnetization measurements up to 300K have already confirmed the existence of this intermediate phase [3].

We performed THz absorption measurements at temperatures between 5-350K, and observed the magnon spectrum of the conical phase. The phase transitions and their hysteresis were observed at 300 and 350K.

[1] J. Moreau, et al., J. Phys. Chem. Solids 32, 1315 (1971).
[2] Z. V. Greeva, et al., Phys. Rev. B 87, 214413 (2013).
[3] S. Kawachi, et al., Phys. Rev. Mat. 1, 024408 (2017).

MA 32.2 Wed 9:45 HSZ 401

Metastable transverse conical state in multiferroic BiFeO3 — •Boglarka Toth[1], Daniel Gergely Farkas[1], Jonathan S. White[2], Istvan Kezsmarki[3], Toshimitsu Ito[4], and Sandor Bordacs[1] — [1]Budapest University of Technology and Economics, Physics Department — [2]Paul Scherrer Institute — [3]University of Augsburg — [4]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, 305-8562 Ibaraki, Japan

Magnetoelectric multiferroic materials with coexisting ferroelectric and magnetic orders have received much attention as they may find applications in low power consumption magnetoelectric memories and data storage devices. Among these materials, $BiFeO_3$ is a unique compound as it is multiferroic even at room temperature, which is essential for future applications. Although $BiFeO_3$ is the most studied multiferroic material, its magnetic phase diagram is not fully understood. Due to the ferroelectric distortion, the so-called Dzyaloshinskii-Moriya interaction is allowed, which, competing with the Heisenberg interaction, results in a cycloidal structure below T_N = 640 K in zero field. We investigated the magnetic phases above room temperature using magnetization measurements and small-angle neutron scattering (SANS) and found a transverse conical state between the zero-field cycloidal state and the high field canted antiferromagnetic phase. Furthermore, the conical state with large magnetoelectric effect remains (meta)stable in zero-field after decreasing the magnetic field.

MA 32.3 Wed 10:00 HSZ 401

Magneto-electric properties and low-energy excitations of multiferroic $FeCr_2S_4$ — •Ana Strinic[1], Stephan Reschke[1], Zhe Wang[1], Michael Schmid[1], Alois Loidl[1], Vladimir Tsurkan[1,2], and Joachim Deisenhofer[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86159 Augsburg, Germany — [2]Institute of Applied Physics, Academy of Sciences of Moldova, MD-2028 Chisinau, Republic of Moldova

$FeCr_2S_4$ is under investigation for over four decades and shows remarkable magnetic as well as electronic properties. While a paramagnetic state is present at room temperature, for low temperatures long-range ferromagnetic order stets in and is followed by an incommensurate magnetic structure. Below T = 10 K a multiferroic ground state with orbital ordering is reached and IR phonons indicate a loss of inversion symmetry [1][2][3]. We report on the low-frequency optical excitations measured by THz spectroscopy. We measured the magnetic field dependence within the temperature range of orbital ordering and the temperature dependence of the different phases within the H-T-phase diagram for several polarizations of the THz-radiation in relation to the applied magnetic field. We will discuss the origin of the low-energy excitations and their relation with multiferroic properties of $FeCr_2S_4$.

[1] J. Bertinshaw *et al.*, Scientific Reports, 4, (2014).
[2] L. Lin *et al.*, Scientific Reports, 4, (2014).
[3] J. Deisenhofer *et. al.*, Physical Review B, 100, (2019).

MA 32.4 Wed 10:15 HSZ 401

Evidence for existence of electromagnon in the multiferroic phase of Cu(II)O: A novel type polarized neutron scattering study at the thermal triple-axis spectrometer PUMA@FRM II — •Avishek Maity[1,2], Steffen Schwesig[1], Fabian Ziegler[1], Oleg Sobolev[1], and Götz Eckold[1] — [1]Institute for Physical Chemistry, Georg-August-University of Göttingen, 37077 Göttingen, Germany — [2]Heinz Maier-Leibnitz Zentrum (FRM II), Technical University of Munich, 85748 Garching, Germany

Since the spontaneous electric polarization was discovered in one of its anti-ferromagnetic (AFM) phases AF2 with T_n = 230 K [1], Cu(II)O regained the focus of research as a model compound for high-temperature type-II multiferroics. The ferroelectricity in the AF2 phase is induced by the cycloidal spin arrangement due to an anisotropic super-exchange interaction (DM) leading to an interesting coupling between spinwave and optical phonon namely electromagnon which is the elementary excitations involving in the magnetoelectric coupling [2]. Here we present the results from polarized neutron scattering to characterize low-energy magnetic excitations in the multiferroic phase of CuO using a novel type of polarization analysis available at the thermal triple-axis spectrometer PUMA@FRM II allowing the simultaneous detection of spinflip and non-spinflip scattering. We have determined energy gaps of several magnon modes and evidenced the signature for the existence of electromagnons near 3 and 13 meV [3].

Refs: [1] Kimura *et al.*, Nat. Mat. 7, 291 (2008). [2] Cao *et al.*, Phys. Rev. Lett. 114, 197201 (2015). [3] Maity *et al.* 2019 (submitted).

MA 32.5 Wed 10:30 HSZ 401

Quantifying multiferroic domain population by nuclear magnetic resonance spectroscopy — •Thomas Gimpel[1], Markus Prinz-Zwick[1], Caroline Steinbrecht[1], Norbert Büttgen[1], Vladimir Tsurkan[1,2], and István Kézsmárki[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86135 Augsburg, Germany — [2]Institute of Applied Physics, Academy of Sciences of Moldova, Academiei strada 5, Chisinau, Republic of Moldova

We demonstrate that nuclear magnetic resonance spectroscopy can be used to measure the volume fraction of multiferroic domains. This new technique is applicable to anisotropic magnets where the different multiferroic domains are characterized either by different orientations of the magnetization or by different forms of the hyperfine coupling or the quadrupole interactions. The latter case is realized, e.g., in type-I mutliferroics where the ferroelectric domains have non-collinear polar axes. We carried out a proof-of-concept study on GaV_4Se_8 which has recently gained interest due to its multiferroic behavior and for hosting Néel-type magnetic skyrmions. This material becomes ferroelectric below 42 K - where four polar domains with polar axes along the cubic <111>-type axes emerge - and orders magnetically below 18 K. Its multiferroic domain population can be controlled either by magnetic or by electric fields. By our new method we can directly quantify the volume fraction of each of the four domains.

15 min. break.

MA 32.6 Wed 11:00 HSZ 401

Revealing the antiferromagnetic spin density in multiferroic $Ba_2CoGe_2O_7$ — •Henrik Thoma[1], Vladimir Hutanu[2], Manuel Angst[3], Georg Roth[4], and Thomas Brückel[3] — [1]Jülich Centre for Neutron Science JCNS at MLZ, 85747 Garching, Germany — [2]Institute of Crystallography, RWTH Aachen and Jülich Centre for Neutron Science JCNS at MLZ, 85747 Garching, Germany — [3]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute PGI, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [4]Institute of Crystallography, RWTH Aachen, 52056 Aachen, Germany

Polarized neutron diffraction (PND) is a powerful method which provides direct access to the scattering contribution from nuclear-magnetic interference and thus reveals the phase difference between the nuclear and magnetic structure. Generally limited to the case of centrosymmetric structures in the paramagnetic state, this information can be used to construct spin density maps and local susceptibility tensors in order to study the anisotropy between magnetic interactions. Introducing an advanced approach in the maximum-entropy method for a model-free reconstruction of spin densities, these limitations were overcome. PND was applied to study the magnetic anisotropy in the non-centrosymmetric unconventional multiferroic $Ba_2CoGe_2O_7$. Using the new approach, a detailed 3D spin density distribution in the unit cell was obtained for the first time both in the paramagnetic and antiferromagnetic ground state. The obtained results clearly show the 2D character of the magnetic interactions in the title compound and are compared to the results of regular magnetic structure refinement.

MA 32.7 Wed 11:15 HSZ 401

In situ electric and magnetic control of conductive domain walls in multiferroic GaV_4S_8 — •Somnath Ghara, Korbinian Geirhos, Vladimir Tsurkan, Peter Lunkenheimer, and István Kézsmárki — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

GaV_4S_8, the lacunar spinel compound, has recently attracted interests due to the presence of different modulated magnetic phases, including Néel-type skyrmions and multiferroic properties. This compound undergoes a transition to the polar rhombohedral ($R3m$) state at T_{JT} = 45 K and a subsequent magnetic transition at T_C = 13 K. In the present work, by polarization and magnetic susceptibility studies, we demonstrate that the population of the four polar domains, with polarization along the four cubic < 111 >-type directions, can be controlled in situ both by electric and magnetic fields. Most interestingly, the dc conductivity of the polar multi-domain state is 10^6 times higher than that of the mono-domain state, indicating the presence of conductive domain walls. Correspondingly, when tuning the domain wall density by magnetic fields, we could achieve a giant magnetoresistance as high as 10^8 %. Furthermore, the conductivity of the domain walls shows a strong non-linearity, in contrast to the bulk.

MA 32.8 Wed 11:30 HSZ 401

Dielectric loss in spiral magnets — •Francesco Foggetti[1,2], Andrei Pimenov[3], and Sergey Artyukhin[1] — [1]Istituto Italiano di Tecnologia, Genova, Italy — [2]Università di Genova, Genova, Italy — [3]Institut für Festkörperphysik, Wien, Austria

Magnetic frustration often results in non-trivial spin textures. Spiral spin structures are common in magnetic perovskites due to competing exchange interactions and may give rise to ferroelectric polarization via inverse Dzyaloshinskii-Moriya mechanism. Here we model chiral domain walls in the spiral magnetic order and characterize the excitation spectrum using a model Hamiltonian describing spins interacting with polar ionic displacements. Results suggest that high dielectric constant in spiral multiferroics (i.e. $TbMnO_3$, $MnWO_4$) originates from contributions of soft domain wall-localized electromagnons and that spiral order may play a fundamental role in the giant magneto-electric effect, observed in proximity of a phase transition from collinear antiferromagnetic order to a conical spiral in Ni_3TeO_6.

MA 32.9 Wed 11:45 HSZ 401

Depth-resolved magnetism in La0.67 Sr0.33 MnO3/PMN-PT as a function of applied electric field — •Tanvi Bhatnagar[1,2], Anirban Sarkar[1], Emmanuel Kentzinger[1], Andras Kovács[2], Qianqian Lan[2], Patrick Schöffmann[3], Annika Stellhorn[1], Markus Waschk[1], Brian Kirby[4], Alexander Grutter[4], Rafal Edward Dunin-Borkowski[2], and Thomas Brückel[1] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institute (PGI-4), JARA-FIT, 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute (PGI-5), 52425 Jülich, Germany — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS) at MLZ, 85747 Garching, Germany — [4]NIST Center for Neutron Research, NIST, Gaithersburg, MD

The magnetic depth profile of an epitaxially-grown artificial multiferroic ferromagnetic/ (ferroelectric, piezoelectric) La0.67Sr0.33MnO3/0.7(Pb(Mg1/3Nb2/3)O3)-0.3(PbTiO3)(001) heterostructure is studied using polarized neutron reflectometry, revealing changes in interfacial magnetism when a voltage is applied between the layers. For a better understanding of the results, structural characterization of the interfacial morphology is performed using transmission electron microscopy.

MA 32.10 Wed 12:00 HSZ 401

Polarized neutron reflectometry of magneto-electric coupling in Fe_3O_4/PMN-PT(011) artificial multiferroic heterostructures — •Patrick Schöffmann[1], Anirban Sarkar[2], Tanvi Bhatnagar[2,3], Mai Hussain Hamed[4], Stephan Geprägs[5], Emmanuel Kentzinger[2], Annika Stellhorn[2], Brian Kirby[6], Alexander Grutter[6], Sabine Pütter[1], Martina Müller[4], and Thomas Brückel[2] — [1]Forschungszentrum Jülich GmbH, JCNS@MLZ, Garching, Germany — [2]Forschungszentrum Jülich GmbH, JCNS-2 and PGI-4, JARA-FIT, Jülich, Germany — [3]Forschungszentrum Jülich GmbH, ER-C-1 and PGI-5, Jülich, Germany — [4]Forschungszentrum Jülich GmbH, PGI-6, Jülich, Germany — [5]Walther-Meißner Institute, BAdW, Garching, Germany — [6]NIST Center for Neutron Research, NIST, Gaithersburg, USA

Magnetoelectric coupling phenomena in artificial thin film heterostructures have attracted attention because of the rich application possibilities in data storage and novel devices. Growing a ferrimagnetic Fe_3O_4 thin film on a ferroelectric $[Pb(Mg_{1/3}Nb_{2/3})O_3]_{0.7}$-$[PbTiO_3]_{0.3}$ (PMN-PT) substrate in (011) orientation constitutes a heterostructure that allows for control of magnetic properties via an applied out-of-plane voltage. Using SQUID magnetometry and polarised neutron reflectometry, a clear change in magnetisation strength and orientation through the sample depth can be observed, upon the application of voltage. The effects are different along the in-plane axes (100) and $(01\bar{1})$.

MA 33: Correlation Theory I

Time: Wednesday 9:30–12:15 Location: HSZ 403

MA 33.1 Wed 9:30 HSZ 403

Electronic and magnetic state of LMO/STO heterostructures: Effect of local correlation and nonlocal exchange — •Hrishit Banerjee[1], Oleg Janson[2], Karsten Held[3], Tanusri Saha-Dasgupta[4], and Markus Aichhorn[1] — [1]TU Graz, Austria — [2]IFW Dresden, Germany — [3]TU Wien, Austria. — [4]S. N. Bose National Centre for Basic Sciences, Kolkata, India

Motivated by the puzzling report of a ferromagnetic insulating state in $LaMnO_3$ (LMO)/$SrTiO_3$ (STO) heterostructures, we calculate the electronic and magnetic state of LMO, strained to a STO square substrate. We use 3 different computational approaches: (a) DFT+U, (b) DFT + DMFT, and (c) DFT + HF as a hybrid functional. While the first two approaches include local correlations and exchange at Mn sites, treated in a static and dynamic manner, respectively, the last one takes into account the effect of nonlocal exchange at all sites. We find in all 3 approaches that compressive strain induced by square substrate of STO turns LMO to a ferromagnet with suppressed Jahn-Teller distortion, in agreement with experiment. The hybrid calculations result in a ferromagnetic insulating solution, found to arise from an electronic charge disproportionation. When correlations are included through DMFT, first a paramagnetic insulating and then on inclusion of magnetism, a ferromagnetic insulating state is observed for strained LMO. Our conclusions remain valid when we investigate LMO/STO within the experimental setup of a superlattice geometry using hybrid functionals. DMFT calculations show the presence of a paramagnetic insulating state. Ref.: Phys. Rev. B 100, 115143 (2019)

MA 33.2 Wed 9:45 HSZ 403

A critical assessment of the Hubbard U correction in the calculation of spin state energetics — •Antonio Lorenzo Mariano and Roberta Poloni — Univ. Grenoble-Alpes, CNRS, Grenoble-INP, SIMaP, Grenoble 38000, France

During the past few years there has been much effort towards the accurate description of spin-state energetics in Fe(II) molecular complexes using ab initio methods. Within density functional theory, large deviations in the adiabatic energy difference between low spin (LS) and high spin (HS) are found among different families of XC functionals. Semilocal functionals overstabilize LS while Hartree-Fock overstabilizes HS. Global hybrids, metaGGAs and density-corrected approaches have also been suggested. In our work, we provide a critical assessment of the Hubbard U approach in the description of spin-state energetics and explain the origin of the overly destabilized LS state. Comparing LDA+U and PBE+U results against coupled cluster-corrected multireference perturbation theory values, i.e. CASPT2/CC [1], for a large series of molecular complexes, our study further explains that the reasonably good performance of LDA+U reported so far arises from a cancellation of errors [2]. [1] K. Pierloot et al., J. Chem. Theory Comput., 14, 2446-2455 (2018). [2] L. A. Mariano et al., to be submitted.

MA 33.3 Wed 10:00 HSZ 403

Implementation of the DFT+Hubbard-I method in FLEUR and application to 4*f* materials — •Henning Janssen[1], Stefan Blügel[1], Gustav Bihlmayer[1], Alexander B. Shick[2], and Jindřich Kolorenč[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics ASCR, CZ-18221 Prague, Czech Republic

The treatment of systems with strongly correlated electrons from first principles is a topic of big interest, e.g. for the description of the magnetic properties of lanthanides. The Hubbard-I method [1] method embeds a single impurity Anderson model, which describes the correlated orbital, into density functional theory (DFT) calculations and approximates the former by neglecting any interactions with the outside bath, i.e. hybridization with other orbitals. We discuss its implementation in the full potential linearized augmented planewave (FLAPW) method as realized in the FLEUR code [2].

In the course of the implementation, the calculation of local Green's function inside the muffin-tin spheres in the FLAPW framework is performed. Using Andersen's local force theorem Green's functions can also be used to calculate the magnetic properties of Heisenberg-like systems. The calculation of the spin stiffness is performed for bulk cobalt and iron, while the Hubbard-I procedure is applied to the test systems of gadolinium and europium.

[1]: A. B. Shick et al., Phys. Rev. B **80**, 085106 (2009)
[2]: www.juDFT.de

MA 33.4 Wed 10:15 HSZ 403

Electronic, Magnetic and Topological Properties of Ca1K1Fe4As4 — •Niclas Heinsdorf[1], Dominik Lessnisch[1], Mikel Iraola Iñurrieta[2], Steve Winter[1], Vladislav Borisov[1,3], and Roser Valentí[1] — [1]Institut für theoretische Physik, Goethe Universität, Frankfurt — [2]Donostia International Physics Center, Donostia/San Sebastian — [3]Department of Physics and Astronomy, University of Uppsala

The 1144 family of Fe-based superconductors, such as Ca1K1Fe4As4, respresents one of the most recent additions to high-Tc superconductors. This family shows a very rich phase diagram as a function of doping and pressure, including superconductivity, spin-vortex magnetism and collapsed tetragonal states. In this talk we will discuss the magnetism and topological properties of Ca1K1Fe4As4 through a combination of DFT, analysis of Elementary Band Representations and effective model calculations.

MA 33.5 Wed 10:30 HSZ 403

Competition of Hund's and spin-orbit couplings in cubic d^4 halides — •Alexander Yaresko[1], Hiroto Takahashi[1,2], and Hidenori Takagi[1,2,3] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]Department of Physics, The University of Tokyo, Bunkyo-ku, Tokyo 133-0022, Japan — [3]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In transition metal compounds with more than one *d*-electron or hole Hund's coupling J_H and pin-orbit coupling ξ compete. The competition manifests itself in the contrast between the *LS*-coupling and the *jj*-coupling schemes in the large J_H and large ξ limits, respectively. Cubic double-perovskite-like K_2RuCl_6 and K_2OsCl_6 compounds with t_{2g}^4 Ru^{4+} and Os^{4+} at the center of a regular Cl_6 octahedron are expected to be non-magnetic $J_{eff} = 0$ Mott insulators; with the former being closer to the *LS*- and the latter to the *jj*-coupling limit. We performed LDA+U calculations using J_H as a tunable parameter which reveal that a transition from a non-magnetic to magnetic insulating ground state is controlled by the ratio J_H/ξ. With realistic parameters of J_H, K_2RuCl_6 is placed in the LS-coupling regime and K_2OsCl_6 is at the border between the two schemes.

15 min. break.

MA 33.6 Wed 11:00 HSZ 403

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 with pair exchange interactions derived from the magnetic force theorem [1]. The resulting formula involves one-particle Green's functions and effective velocity operators appearing in a recent theory of electron transport [2]. Application of this approach to clean crystals allows one to overcome the problem of nonconvergent 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] A. I. Liechtenstein et al., J. Magn. Magn. Mater. 67 (1987) 65.
[2] I. Turek et al., Phys. Rev. B 65 (2002) 125101.

MA 33.7 Wed 11:15 HSZ 403

Fractional quantum Hall models on lattices — •Srivatsa Nagara Srinivasa Prasanna — MPIPKS, Dresden

Conformal field theory has recently been applied to derive few-body Hamiltonians whose ground states are lattice versions of fractional quantum Hall states. The exact lattice models involve interactions over long distances, which is difficult to realize in experiments. It seems, however, that such long-range interactions should not be necessary, as the correlations decay exponentially in the bulk. This poses the question, whether the Hamiltonians can be truncated to contain only local interactions without changing the physics of the ground state. Previous studies have, in a couple of cases with particularly much symmetry, obtained such local Hamiltonians by keeping only a few local terms and numerically optimizing the coefficients. Here, we investigate a different strategy to construct truncated Hamiltonians, which does not rely on optimization, and which can be applied independently of the choice of lattice.

MA 33.8 Wed 11:30 HSZ 403

Ab-initio calculations of magnetic properties of Ba_2YIrO_6 — •Hermann Schnait — TU Graz

The strongly correlated double perovskite Ba_2YIrO_6 (electronic configuration $5d^4$) shows unexpected magnetic properties in experiment. We investigate this behaviour using DFT+DMFT techniques including spin-orbit coupling, within the t_{2g} manifold.

As some experiments claim a magnetic ordering temperature of about 3K and CTQMC impurity solvers would not be able to yield results in this regime, a novel MPS-based solver for multi-orbital systems (Fork-Tensor Product States - FTPS) is employed for T=0K calculations. The magnetic moment is measured both at T=0K and at finite temperatures and possible long-range antiferromagnetic ordering is investigated.

MA 33.9 Wed 11:45 HSZ 403

Non-local Correlation and Interaction Effects on the Phase Diagram of the Kane-Mele-Hubbard Model — •Markus Richter — TU-Graz, Austria

We use the honeycomb lattice as a playground to investigate the effects of strong correlations, non-local interactions, and spin-orbit coupling, using one orbital per site at half filling.

The model Hamiltonian of our choice is the extended Kane-Mele Hubbard model. This model provides, besides the unordered phase, two ordered phases, namely spin-density waves (SDW) and charge-density waves (CDW), as well as the additional characterization of being topologically trivial or non-trivial.

To analyze the interplay between the different phases we calculate phase diagrams using the different methods (extended) DMFT and TRILEX (triply irreducible local expansion). Unlike (E)DMFT, within TRILEX the self-energy becomes also k-dependent due to local vertex corrections.

MA 33.10 Wed 12:00 HSZ 403

Theoretical study of the homo-trinuclear magnetic molecule $[Fe_3O(COOCH_3)_6(H_2O)_3]$ — •Rui Shi, Georgios Lefkidis, and Wolfgang Hübner — Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany

In close collaboration with experiment we study the magnetic properties of the recently synthesized mixed-valence trinuclear iron acetate complex $[Fe_3O(COOCH_3)_6(H_2O)_3]$, which, like similar iron complexes, can boost the design of nanospintronic devices [1].

We optimize the structure geometry using the coupled-cluster method with single and double excitations (CCSD), and compute the electronic excited states with the equation-of-motion coupled-cluster method (EOM-CCSD) and perturbative inclusion of spin-orbit coupling. The infrared (IR) spectrum is numerically calculated through the energy gradient along the normal modes at the CCSD level [2], with an active window for the electronic correlations of 100 molecular orbitals. We find that the correlations substantially improve the vibration frequencies (up to 100 cm^{-1}) with respect to the Hartree-Fock resuls. Most notably, we theoretically compute the magnetic circular dichroism spectrum (MCD) and achieve excellent agreement with all five peaks detected in the experimental frequency window.

[1] H. Du, J. Liu, N. Zhang, J. Chang, W. Jin, C. Li, G. Lefkidis, and W. Hübner, Phys. Rev. B **99**, 134430 (2019)
[2] D. M. Becherer, D. Bellaire, F. Dietrich, M. Gerhards, G. Lefkidis, and W. Hübner, Phys. Rev. B **97**, 224404 (2018)

MA 34: Skyrmions II (joint session MA/TT)

Time: Wednesday 9:30–13:00 Location: POT 6

Invited Talk MA 34.1 Wed 9:30 POT 6

Anatomy of skyrmion-defect interactions and their impact on detection protocols — •Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Magnetic skyrmions are topological swirling spin-textures with enormous potential for new technologies that store, transport and read information. However, imperfections are intrinsic to any real device, affecting the detection, nucleation, type of motion and velocity of a skyrmion. I will discuss our first-principles investigations of the electronic, magnetic and transport properties of single skyrmions interacting with 3d and 4d impurities embedded in PdFe/Ir(111). We found that the obtained energy landscape has a universal shape as function of the defect's electron filling, enabling predictions of the repulsive or attractive nature of the impurity [1]. This finding can be used to design complex energy profiles with targeted properties via atom-by-atom manufacturing of multi-atomic defects. Finally, I address how the latter affect the electronic structure and the chiral orbital magnetism, with consequences for the efficiency of skyrmion detection protocols, either all-electrical [2,3] or optical [4]. — Work done with I. L. Fernandes, J. Bouaziz, D. M. Crum, M. dos Santos Dias, M. Bouhassoune, I. Gede Arjana, J. Chico and S. Blügel and supported by the EU Horizon 2020 via ERC-consolidator Grant No. 681405–DYNASORE.

[1] Fernandes *et al.*, Nat. Commun. **9**, 4395 (2018); [2] Fernandes *et al.*, ArXiv:1906.08838; [3] Crum *et al.*, Nat. Commun. **6**, 8541 (2015); [4] dos Santos Dias *et al.*, Nat. Commun. **7**, 13613 (2016)

MA 34.2 Wed 10:00 POT 6

Electrical and optical manipulation of magnetic skyrmions — •Felix Büttner[1], Bastian Pfau[2], Lucas Caretta[1], Kai Litzius[1], Michael Schneider[2], Guiseppe Mercurio[3], Marie Böttcher[4], Bertrand Dupé[4], Johan Mentink[5], Stefan Eisebitt[2], and Geoffrey Beach[1] — [1]MIT, Cambridge, MA, USA — [2]MBI, Berlin, Germany — [3]XFEL, Hamburg, Germany — [4]University of Mainz, Germany — [5]RU Nijmegen, The Netherlands

Magnetic skyrmions are nanoscale twisted spin textures with a topology equivalent to the unit sphere. Skyrmions exhibit fascinating quasi-particle physics, including skyrmion gyration [1], inertia [1], the skyrmion Hall effect [2], topological damping [3], sub-ns switching [4], and ultra-fast motion [5]. They are also promising candidates for several data storage and data processing technologies. In this context, fast and energy efficient operation is key. In this talk I will give a brief overview of our latest results of on skyrmion displacement by nanosecond spin-orbit torque current pulses and ultrafast light pulses. The main part of the talk will focus on the physics and speed of optically induced topological switching (skyrmion nucleation) and how this is different from classical bubble behavior. These results will be discussed from a theoretical and experimental perspective.

[1] Büttner et al., Nat Phys 11, 225 (2015). [2] Litzius et al., Nat Phys 13, 170 (2017). [3] Büttner et al., Sci Rep 8, 4464 (2018). [4] Büttner et al., Nat Nano 12, 1040 (2017). [5] Caretta et al., Nat Nano 13, 1154 (2018).

MA 34.3 Wed 10:15 POT 6

Manipulation of magnetization and spin textures via femtosecond laser — •Nina Novakovic[1,2], Mohamad-Assaad Mawass[1], Oleksii Volkov[3], Wolfgang-Dietrich Engel[4], Denys Makarov[3], and Florian Kronast[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489, Berlin, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24/25, 14476, Potsdam, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf e. V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [4]Max Born Institute Berlin, Max-Born-Str. 2A, 12489 Berlin, Germany

Ultrafast optical control of magnetization recently became a rising field of study in magnetic thin film research, as micrometer sized domains manipulated at a small timescale may lead to faster and denser memory devices. We investigate different magnetic textures, such as bubbles and skyrmions under the influence of femtosecond laser pulses by means of photoelectron emission microscopy.

We present helicity dependent transition between stripe and bubble domains in CoPt multilayers. Moreover, manipulation of individual bubbles by tuning down laser fluence and external field is demonstrated. With the introduction of Ta layer at the interface in the CoPt system, we increase the influence of DMI. This allows us to study the formation and annihilation of skyrmions via fs laser and discuss important parameters which are required to attain reliable and efficient helicity dependent switching process, such as magnetic field and laser fluence and polarization.

MA 34.4 Wed 10:30 POT 6

Quantum Damping of Characteristic Skyrmion Eigenmodes due to Spontaneous Magnon Decay — •Alexander Mook, Jelena Klinovaja, and Daniel Loss — Department of Physics, University of Basel, CH-4056 Basel

The three characteristic and magnetically active modes of skyrmion crystals, i.e., the anticlockwise, breathing, and clockwise mode [1], are experimental probes that reveal information on the stability and behavior of the topologically nontrivial magnetic texture.

Herein, we show that the combination of a noncollinear texture and lowly dispersive Landau-level-like nature of magnon bands in skyrmion crystals installs strong three-particle interactions. These lead to spontaneously decaying magnons, i.e., to an intrinsic zero-temperature quantum damping, which manifests as lifetime broadening of the quasiparticle peak in the spectral function.

By varying the external magnetic field the characteristic modes can be brought "in resonance" with a flat mode, strongly enhancing their damping. This finding establishes skyrmion crystals as a platform to study the quantum mechanical phenomenon of spontaneous quasiparticle decay.

[1] M. Mochizuki, Phys. Rev. Lett. **108**, 017601 (2012)

MA 34.5 Wed 10:45 POT 6

Current-driven magnetic Skyrmions in constrained geometries — •Martin Stier[1], Richard Strobel[1], Wolfgang Häusler[2], and Michael Thorwart[1] — [1]Universität Hamburg, Jungiusstraße 9, 20355 Hamburg — [2]Universität Augsburg, Universitätsstr. 1, 86135 Augsburg

From a principle point of view, magnetic Skyrmions are ultimately stable and thus do basically not interact with their environment. This is in stark contrast to experimental findings, where Skyrmions are strongly influenced by the shape, roughness and the quality of the sample. We show how the current-driven dynamics and the number of Skyrmions are influenced by geometric constrictions in the wire, its edge roughness and magnetic impurities within the material. We discuss several scenarios in detail, e.g., Skyrmion trapping or acceleration, and Skyrmion destruction or creation. These findings may help to develop tailored microscopic memory devices involving Skyrmions.

MA 34.6 Wed 11:00 POT 6

Evolution of topological charge during transitions between magnetic states — •Igor Lobanov — ITMO University, Saint Petersburg, Russia — Saint Petersburg State University, Russia

Stability of magnetic skyrmions and other topological structures is an important prerequisite for the development of magnetic storage and computing devices. Evaluation of lifetime of magnetic states and the most probable transition scenario can be performed using harmonic transition state theory [1,2] and minimum energy path (MEP) calculation. Results on annihilation of skyrmionium to the ferromagnetic state are presented. There, the initial state and the final state are both of zero topological charge, but the charge is not necessarily conserved during the transition between the states. Several MEPs for the skyrmionium annihilation are identified, corresponding activation energies and transition rates are systematically compared, while variation of the topological charge along each MEP is analyzed. The dependence of lifetime on the lattice constant is studied, the resulting switching of the preferable path is demonstrated. The calculated MEPs give us a hint for optimal control of nucleation and annihilation of topologically protected structures.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138).

1. G. Fiedler, J. Fidler, J. Lee, T. Schrefl, R. L. Stamps, H. B. Braun, and D. Suess, J. Appl. Phys. 111, 093917 (2012)

2. P.F. Bessarab, V.M. Uzdin, H. Jonsson, Phys. Rev. B 85, 184409 (2012)

15 min. break.

MA 34.7 Wed 11:30 POT 6

Topological Phase Transition Controls Magnon Spin Currents — •Sebastián A. Díaz[1], Tomoki Hirosawa[2], Jelena Klinovaja[1], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Basel, Switzerland — [2]Department of Physics, University of Tokyo, Tokyo, Japan

Using magnons in insulating magnets as information carriers is a highly promising approach for low-power consumption devices free of Joule heating. Here we show that a ferromagnetic skyrmion crystal provides a novel platform for switchable magnon currents. Taking advantage of a topological phase transition in the magnon spectrum, we show that an external magnetic field allows one to turn on and off chiral magnon currents carried by topological edge states. We identify concrete systems for experimental implementations. Our proposal establishes a profound connection between the fields of magnetic skyrmions and topological magnonics controlled by magnetic fields.

[1] S. A. Díaz, T. Hirosawa, J. Klinovaja, and D. Loss, arXiv:1910.05214.

MA 34.8 Wed 11:45 POT 6

Mixed Topology Ring States in skyrmions of mixed Weyl semimetals — •Matthias Redies[1,2], Fabian Lux[1,2], Patrick Buhl[3], Jan-Phillip Hanke[1], Stefan Blügel[1], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany

Various properties of Weyl semimetals are currently attracting significant attention. Recently, the concept of a magnetic mixed Weyl semimetal (MWS) has been put forward e.g. in 2D ferromagnets [1], and various prospects of these materials have been suggested. In such 2D materials the Weyl points are exhibited in the mixed space of **k**-vectors and the magnetization direction. We investigate the effect that skyrmionic order has on electronic transport properties of MWSs. Our analysis reveals the emergence of robust ring-like edge states, carrying local orbital moment, which mediate the transition between two different Chern insulator phases appearing in the skyrmion lattice of MWSs. We discuss the properties of such mixed topology ring states and their possible applications.

We acknowledge funding from Deutsche Forschungsgemeinschaft

(DFG) through SPP 2137 “Skyrmionics".

[1] Hanke *et al.*, Nature Comm. **8**, 1479 (2017), ibid. **10**, 3179 (2019)

MA 34.9 Wed 12:00 POT 6

Skyrmion Breathing Modes in Synthetic Ferri- and Antiferromagnets — •Martin Lonsky and Axel Hoffmann — Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801, United States of America

Magnetic multilayers that combine strong spin-orbit interaction with lacking inversion symmetry can give rise to the presence of topologically nontrivial spin textures, so-called magnetic skyrmions, at room temperature. Recent studies have indicated strongly enhanced propagation velocities of skyrmions in antiferromagnets and compensated ferrimagnets [1]. At the same time, it is unclear how magnetic compensation may affect dynamic excitations of magnetic skyrmions, such as breathing modes which entail an oscillation of the skyrmion size at GHz frequencies [2]. Here, we present micromagnetic simulations of these excitations in synthetic ferri- and antiferromagnets. The observed features in the calculated power spectra show a systematic dependence on the coupling strength between the individual magnetic layers and are related to pure breathing modes as well as to hybridizations of breathing and spin wave modes that are characteristic for the considered geometry. Based on these simulations, we then discuss the impact of these results for potential skyrmion sensing and other applications.

This work is supported by the Deutsche Forschungsgemeinschaft (DFG) through the research fellowship LO 2584/1-1.

[1] L. Caretta et al., Nat. Nanotechnol. 13, 1154-1160 (2018)
[2] M. Garst et al., J. Phys. D: Appl. Phys. 50, 293002 (2017)

MA 34.10 Wed 12:15 POT 6

Spin waves in skyrmions with various topological charges — •Levente Rózsa and Ulrich Nowak — Universität Konstanz, Konstanz, Deutschland

Magnetic skyrmions offer promising prospects for the development of magnonic devices. The most widely studied mechanism to date for the stabilization of skyrmions is the Dzyaloshinsky-Moriya interaction (DMI). Although a wide variety of localized spin wave modes has been predicted theoretically in DMI-stabilized skyrmions [1], their experimental observation via excitation by a homogeneous external field has been restricted to breathing and gyrational modes. This can be attributed to the angular momentum selection rules enforced by the cylindrically symmetric spin structure. In contrast to the DMI, frustrated Heisenberg exchange interactions (FHEI) may stabilize different types of skyrmions with various topological charges [2]. Here we theoretically investigate how the types of localized magnons and the selection rules are modified in FHEI-stabilized skyrmions. The competition between FHEI and DMI is also considered, which was demonstrated to distort the shape of the different types of skyrmions [3].

[1] M. Garst et al., J. Phys. D: Appl. Phys. **50**, 293002 (2017).
[2] A. O. Leonov et al., Nat. Commun. **6**, 8275 (2015).
[3] L. Rózsa et al., Phys. Rev. B **95**, 094423 (2017).

MA 34.11 Wed 12:30 POT 6

Transverse susceptibility of skyrmion lattice order in Cu_2OSeO_3 and MnSi — •Denis Mettus[1], Felix Rucker[1], Andreas Bauer[1], Helmuth Berger[2], Markus Garst[3], Achim Rosch[4], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]École Polytechnique Federale de Lausanne, Lausanne, Switzerland, Switzerland — [3]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany — [4]Institute for Theoretical Physics, Universität zu Köln, D-50937 Köln, Germany

The observation of skyrmion lattice flow in chiral magnets under spin-transfer torques at exceptionally small spin current densities has generated great interest concerning the underlying pinning and coupling mechanisms. While the spin currents in MnSi represent spin-polarized charge currents, similar spin torque effects due to tiny magnon currents are observed in the electrical insulator Cu_2OSeO_3. We report systematic measurements of the transverse ac susceptibility of MnSi and Cu_2OSeO_3 as a function of the amplitude and frequency of the excitation field. In our study we cover the response of the magnetization in the limits of local scales up to large scales of the entire texture. We discuss our results in the context of unpinning effects due to spin transfer torques as well as different stabiliziation mechanisms of skyrmion lattice order.

MA 34.12 Wed 12:45 POT 6

Skyrmion-Skyrmion and Skyrmion-Edge Interactions studied with SP-STM — •Jonas Spethmann, André Kubetzka, Roland Wiesendanger, and Kirsten von Bergmann — University of Hamburg

For the design of potential skyrmion-based devices, a deep understanding of the interactions between individual skyrmions and between skyrmions and magnetic nanostructure boundaries is fundamental. In order to study these interactions, we investigate the magnetic field dependent size and shape of multiple skyrmions confined in islands of PdFe bilayer on Ir(111) using spin-polarized STM. When the external magnetic field is reduced, the skyrmion size increases [1]. This forces adjacent skyrmions to interact with each other or with the edge of the PdFe island. Such interactions may manifest in form of skyrmion deformation, displacement or annihilation. Due to our operation temperature of 4 K or lower, the skyrmions do not spontaneously revert back to the spin spiral phase at small or even zero magnetic fields. Instead, we obtain metastable topological states, which provide an interesting starting point for further investigations. Additionally, by modification of the PdFe island-edge, we are able to study the influence of different types of edges on the spin spiral state and on the skyrmion-edge interactions.

[1] N. Romming et al., PRL 114: 177203, 2015.

MA 35: PhD Focus Session: Symposium on "Magnetism – A Potential Platform for Big Data?" (joint session MA/AKjDPG/O)

As the title of a recent nature editorial article "Big data needs a hardware revolution" points out, new technologies and hardware architectures are necessary in order to cope with the ever increasing amount of information. Google’s AlphaGo’s success apprised of the potential of parallel computing, yet energy efficiency is a major challenge. Hardware developers came up with mimicking the human brain as the most efficient processor, leading to the field of neuromorphic computing. An immense amount of research is deployed in different fields to screen for fast, low energy consuming and scalable solutions. This focus session is meant to give insight into the current state-of-the-art computing together with its challenges as an introduction. Two major approaches to implement new computation technologies using magnetism, namely, neuromorphic computing based on spintronics, and wave-based computing using magnonics will be presented. A fourth talk, covering the prevailing use of magnetic tape for Big Data storage will give insight into the magnetic backbone of the largest information repositories.

Organizers: Mauricio Bejarano and Tobias Hula (Helmholtz-Zentrum Dresden Rossendorf), Luis Flacke and Lukas Liensberger (Walther-Meissner Institute and TU Munich)

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

Invited Talk MA 35.1 Wed 15:00 HSZ 04

Data Storage and Processing in the Cognitive Era —

•Giovanni Cherubini — IBM Research - Zurich

In this talk, I will present the emerging vision of cognitive data systems. A data system comprises physical devices that provide means to acquire, store and modify data for analytics and communications tasks, with the goal of obtaining high-value information. With the need to deal with exponentially growing amounts of data, however, the system size and complexity present major challenges for data storage and processing. In addition, with the approaching end of Moore's law, there is a dire need to significantly improve the efficiency of data systems in terms of cost and energy. To address these challenges, cognitive data systems will require novel learning algorithms and computing paradigms. The talk will be divided into two parts, focusing on data storage and processing aspects. First, I will present advanced technologies for big data storage systems, with focus on magnetic tape drives of future generations, targeting areal densities of several hundred gigabits per square inch on a flexible medium. Next, I will introduce in-memory computing techniques and devices that are well suited for novel computing systems, which are based on non-von Neumann architectures and aim at achieving the efficiency of the human brain.

Invited Talk MA 35.2 Wed 15:30 HSZ 04

Brain-inspired approaches and ultrafast magnetism for Green ICT — •Theo Rasing — Radboud University, Institute for Molecules and Materials, Heijendaalseweg 135, 6525AJ Nijmegen, the Netherlands

The explosive growth of digital data use and storage has led to an enormous rise in global energy consumption of Information and Communication Technology (ICT), which already stands at 7% of the world electricity consumption. New ICT technologies, such as Artificial Intelligence push this exponentially increasing energy requirement even more, though the underlying hardware paradigm is utterly inefficient: tasks like pattern recognition can be performed by the human brain with only 20W, while conventional (super)computers require 10 MW. Therefore, the development of radically new physical principles that combine energy-efficiency with high speeds and high densities is crucial for a sustainable future. One of those is the use of non-thermodynamic routes that promises orders of magnitude faster and more energy efficient manipulation of bits. Another one is neuromorphic computing, that is inspired by the notion that our brain uses a million times less energy than a supercomputer while, at least for some tasks, it even outperforms the latter. In this talk, I will discuss the state of the art in ultrafast manipulation of magnetic bits and present some first results to implement brain-inspired computing concepts in magnetic materials that operate close to these ultimate limits.

15 min. break.

Invited Talk MA 35.3 Wed 16:15 HSZ 04

How good are spin waves for data processing? — •Andrii Chumak — Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Over the last decade, spin waves and their quanta magnons attract attention as data carriers in novel types of data processing units instead of electrons. Among the advantages proposed by spin waves, one can name added value given by the phase of the wave, pronounced nonlinear phenomena, scalability down to nm sizes, GHz to THz frequency range as well as low-loss information transport [1].

Recently, significant progress in the miniaturization of magnonic elements down to 50 nm took place [2, 3]. Moreover, a spin-wave directional coupler was investigated numerically [4] and realized experimentally on the nano-scale [5]. This is a universal unit allowing for the processing of analog RF and binary-coded digital information and is suitable for novel unconventional computing. E.g., the first integrated magnonic circuit in the form of half-adder was studied numerically [6].

Finally, now we are able to determine the parameters of future magnonic devices. The benchmarking of magnonic circuits with respect to 7 nm CMOS will be presented in the talk.

[1] A.V. Chumak, et al., Nat. Phys. 11, 453 (2015). [2] Q. Wang, B. Heinz, et al., Phys. Rev. Lett. 122, 247202 (2019). [3] B. Heinz, et al., arXiv: 1910.08801 (2019). [4] Q. Wang, P. Pirro, et al., Sci. Adv. 4, e1701517 (2018). [5] Q. Wang, M. Kewenig, et al., arXiv: 1902.02855 (2019). [6] Q. Wang, R. Verba, et al., arXiv: 1905.12353 (2019).

Invited Talk MA 35.4 Wed 16:45 HSZ 04

Unconventional computing with stochastic magnetic tunnel junctions — •Alice Mizrahi[1,2,3,4], Tifenn Hirtzlin[2], Matthew Daniels[3,4], Nicolas Locatelli[2], Akio Fukushima[5], Hit Kubota[5], Shinsi Yuasa[5], MD Stiles[4], Julie Grollier[1], and Damien Querlioz[2] — [1]Unité Mixte de Physique CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, 91767 Palaiseau, France — [2]Centre de Nanosciences et de Nanotechnologies, Univ. Paris-Sud, CNRS, Université Paris-Saclay, 91405, Orsay, France — [3]Maryland NanoCenter, University of Maryland, College Park, Maryland 20742, USA — [4]National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA — [5]Spintronics Research Center, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568, Japan

Magnetic tunnel junctions are bi-stable nanodevices which magnetic state can be both read and written electrically. Their high endurance, reliability and CMOS-compatibility have made them flagship devices for novel forms of computing. While they are mostly used as non-volatile binary memories, they can be made unstable and thus behave as stochastic oscillators. Here, we show how stochastic magnetic tunnel junctions are promising elements for low energy implementations of unconventional computing. An analogy can be drawn between stochastic magnetic tunnel junctions and stochastic spiking neurons. We apply neuroscience computing paradigm to these devices and demonstrate that they can be the building blocks of low energy artificial neural networks capable of on-chip learning.

MA 36: Spin-Dependent 2D Phenomena

Time: Wednesday 15:00–18:00 Location: HSZ 101

Invited Talk MA 36.1 Wed 15:00 HSZ 101

2D Magnetic Materials — •Alberto Morpurgo — University of Geneva, Geneva, Switzerland

The first 2D magnetic material in which ferromagnetism has been shown experimentally to persist down to individual monolayers has been reported less than two years ago. Since then a number of different experiments have been performed on atomically thin magnets of different types, and led to interesting observations (giant tunneling magneto resistance, gate-tuning of the magnetic state, strong exchange bias at van der Waals interfaces, etc.). In my talk I will give a short introduction to this rapidly evolving domain of research, and discuss results obtained in my group on atomically thin multilayers of materials such as CrI3, CrCl3 (layered antiferromagnets) and MnPS3 (antiferromagnetic within individual layers). Most of our experiments focus on investigations of the magnetic properties of atomically thin crystals of these materials by using them to form tunnel barriers and by measuring their tunneling magnetoresistance. As I will show, tunneling magnetoresistance allows tracing the boundaries between different magnetic phases, and it can therefore be used to establish magnetic phase diagrams. Specific phenomena that I will discuss include the observation of a giant tunneling magnetoresistance in CrI3, a complete analysis of the magnetic phases of multilayers of CrCl3 as a function of thickness, magnetic field and temperature, and the observation of a spin-flop transition in MnPS3 persisting to the ultimate thickness of an individual monolayer.

MA 36.2 Wed 15:30 HSZ 101

Strain-induced phase transition in CrI_3 bilayers — •Andrea Leon — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Recent reports on ferromagnetic and antiferromagnetic order in different 2D crystal Van der Waals heterostructures, have opened a vast field of possibilities for new physical phenomena and generation of electronic devices which already started to be explored experimentally. In particular layered CrI_3 systems are of great interest due to the staking dependent magnetism, mechanical/magnetic response under pressure, magnetoelectric and optical properties, between others. Motivated by this, the main goal of this work is to search for new electronic properties of antiferromagnetically coupled CrI_3 bilayer with C2/m symmetry under strain, using DFT calculations and analytic models. We found that strain may be an efficient tool to tune the magnetic phase of the structure. A tensile strain stabilizes the antiferromagnetic phase, while a compressive strain turns the system ferromagnetic. We understood that behavior by looking at the relative displacement between layers due to the strain. We also study the evolution of the magnetic anisotropy, the magnetic exchange coupling between Cr atoms, and how the Curie temperature is affected by the strain.

MA 36.3 Wed 15:45 HSZ 101

Effect of hydrostatic pressure on the magneto-elastic coupling in 2D ferromagnet $Cr_2Ge_2Te_6$ — •Laura T. Corredor-Bohórquez[1], Bastian Rubrecht[1], Gael Bastien[1], Anja U. B. Wolter[1], Sebastian Selter[1], Saicharan Aswartham[1], and Bernd Büchner[1,2] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, 01069 Dresden — [2]Faculty of Physics, Technische Universität Dresden, Dresden

Low–dimensional magnetism is currently a rapidly developing area of research: the existing challenges in this area are mainly associated with the search and improvement of compounds whose characteristics meet the needs of innovative technologies. For exciting new applications such as ultra-compact spintronics or magnonic devices, 2D magnetic order is crucial. Following the recent re-visit of 2D ferromagnetic semiconductor $Cr_2Ge_2Te_6$, a full understanding of the mechanism behind its magnetism is compelling. Two main magnetic nearest-neighbor interactions are theoretically predicted: an AFM direct exchange interaction, and a FM superexchange interaction, being the ground state a result from the competition between them. In order to investigate how the magneto elastic coupling influences the physical properties of this material, we have performed hydrostatic pressure experiments. The magnetic field was applied in the c axis, i.e. the easy-magnetization axis. AFM interaction is enhanced, at the same time that there is a reduction of the FM properties, as predicted earlier from first principle calculations. The roles of competing magnetic interactions and anisotropy with the increase of pressure are discussed.

MA 36.4 Wed 16:00 HSZ 101

Magnetic Anisotropy and Low Field Magnetic Phase Diagram of the Quasi Two-Dimensional Ferromagnet $Cr_2Ge_2Te_6$ — •Sebastian Selter[1,2], Gaël Bastien[1], Anja U. B. Wolter[1], Saicharan Aswartham[1], and Bernd Buechner[1,2] — [1]Institute for Solid State Research, Leibniz IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Institute of Solid State and Materials Physics, Technische Universität Dresden, 01062 Dresden, Germany

All known quasi two-dimensional ferromagnets, such as CrX_3 (X = Br, I) and $Cr_2(Ge,Si)_2Te_6$, exhibit a peculiar temperature dependence of the magnetization under small external fields in the hard plane. Investigating the van der Waals layered compound $Cr_2Ge_2Te_6$ by magnetization and specific heat measurements under magnetic fields, we find the temperature dependence of the effective magnetic anisotropy as plausible explanation for this unusual behavior.

Based on magnetic temperature-field phase diagrams measured with magnetic fields applied along the magnetic easy axis and in the hard plane, the temperature dependence of the effective magnetic anisotropy constant was extracted and its thermal evolution was compared to the corresponding theory. A qualitative scheme is developed explaining the changes of magnetization direction due to the influence of temperature, as well as strength and direction of external magnetic fields in $Cr_2Ge_2Te_6$.

15 min. break.

MA 36.5 Wed 16:30 HSZ 101

Enhancement of Curie temperature in Mn5Ge3 films — •Yufang Xie[1,2], Ye Yuan[1], Hannes Simon Funk[3], Chi Xu[1], Manfred Helm[1,2], Shengqiang Zhou[1], and Slawomir Prucnal[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden Rossendorf, Dresden 01328, Germany — [2]Technische Universität Dresden, Dresden 01062, Germany — [3]Institut für Halbleitertechnik , Universität Stuttgart, Stuttgart 70569, Germany

We report the effects of strain on the structural and magnetic properties of epitaxial Mn5Ge3 on Ge/Si (111) substrate by applying ms-range flash lamp annealing (FLA). The X-ray diffraction results demonstrate that during the FLA process the formation of nonmagnetic secondary phases of Mnx*5Gey*3 is fully suppressed but the layer becomes strained. The temperature-dependent magnetization results indicate that the Curie temperature of Mn5Ge3 increases from 280 K up to 400 K with increasing annealing temperature. The biaxial strain generated in Mn5Ge3 during ms-range FLA modifies the distance between adjacent Mn atoms, which provokes the different ferromagnetic interaction between them. Consequently, the significant increase of Curie temperature is observed.

MA 36.6 Wed 16:45 HSZ 101

Defective Two-Dimensional Ferromagnetic Semiconductors: Magnetic Tailoring and Improved Stability — •Liang Hu[1,2,3], Yujia Zeng[2], Lei Cao[3], Zichao Li[3], Changan Wang[3], Juanmei Duan[3], Slawomir Prucnal[3], and Shengqiang Zhou[3] — [1]College of Materials and Environmental Engineering, Hangzhou Dianzi University, Hangzhou, P. R. China — [2]College of Physics and Optoelectronic Engineering, Shenzhen University, Shenzhen, P. R. China — [3]Institute of Ion Beam Physics and Materials Research, HZDR, Dresden, Germany

2D ferromagnets with high Curie temperature are desirable for spintronic applications. For nonmagnetic van der Waals crystals with atomic thickness, the extrinsic tailoring such as doping or defect-engineering can render them to be ferromagnetic 2D semiconductors. Herein, we introduce three emerging 2D ferromagnetic candidates including mono-element (phosphorene and antimonene) and binary compound (MnSe2). By applying nonmetal/metal ions doping and defect engineering, robust ferromagnetic behaviors (Tc far beyond 300 K) have been accessed by the combination of SQUID, MOKE and MFM characterization tools. Density functional theory calculations show that these defects can be stabilized in 2D systems and contribute to net moment. Furthermore, the well-known issues of stability in thin 2D structures are also addressed, which are highly dependent on the selection of preparation and processing routes. The above merits can excite more intensive research and open a promising way to explore 2D magnets-based device applications.

MA 36.7 Wed 17:00 HSZ 101

Transitional metal doped $Bi_{2-n}X_nO_2Se$ - novel 2D magnetic semiconductor — •Dominik Legut[1], Xiaopeng Liu[2], Ruifeng Zhang[2], Zhongheng Fu[2], Tinshuai Wang[2], Yanchen Fan[2], and Qianfan Zhang[2] — [1]IT4Innovations, VSB-TU Ostrava, Ostrava, Czech Republic — [2]School of Mat. Sci. and Eng., Beihang University, Beijing, China

For the spintronic applications like large data storages (high capacity HDD) the industry searches for ferromagnetic insulators at nanoscale size. Recently the discovery of Bi_2O_2Se/Te phases that exist as 2D material and still are semiconducting attract attention. Here we investigate $Bi_{2-n}X_nO_2Se$ by transitional metal doping to introduce a magnetic spin order. We explore the electronic and magnetic properties of various ferromagnetic (e.g. Fe) or antiferromagnetic (e.g. Mn) transitional metals doped Bi_2O_2Se phases within the framework of density functional theory based electronic structure calculations. We start with the magnetic order of the bulk phase in which the magnetic atoms form interlayer coupling that vary with the type and concentration of doped atoms and go towards the nanoscale dimension, i.e. 2D materials. As a result of the competitions of magnetic interactions the magnetic anisotropy energy is a crucial quantity. In combinations with Monte Carlo simulations we are able to solve the exchange interaction constants for the Heisenberg model and therefore evaluate the Curie temperature to see if these types of materials are suitable to become novel dilute magnetic semiconductors for spintronic applications at room and above temperatures.

MA 36.8 Wed 17:15 HSZ 101

DFT+HIA Description of Rare-Earth Adatoms on Graphene — •Johanna P. Carbone[1,2], Henning Janssen[1], Gustav Bihlmayer[1], Alexander B. Shick[4], Maria Peressi[3], and Stefan Blügel[1] — [1]PGI-1/IAS-1 Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Chemical and Pharmaceutical Sciences, University of Trieste, I-34127 Trieste, Italy — [3]Department of Physics, University of Trieste, I-34127 Trieste, Italy — [4]Institute of Physics ASCR, CZ-18221 Prague, Czech Republic.

Composite 2D-materials containing rare-earth atoms are interesting candidates for quantum technology thanks to their large magnetic moments, rich magnetic interactions and strong spin-orbit coupling effects. The main problem in describing these systems in density functional theory (DFT) using the conventional approximations lies in the strongly localized and correlated 4f-electrons. A promising path is the combination of DFT with the Hubbard-I approximation [1] to the Anderson impurity (DFT+HIA) [2]. The DFT-HIA model has been recently implemented into the FLAPW code FLEUR (www.juDFT.de). Preliminary tests on systems containing lanthanide adatoms on graphene have shown promising results. The goal is now to study complex magnetism and effects such as magnetic anisotropy in novel 2D-materials containing layers of lathanides intercalated between sheets of van der Waals heterostructures.

We acknowledge support from NFFA.eu (ID 693).

[1] Shick et al., Phys. Rev. B 80, 085106 (2009)
[2] Kolorenč et. al., Phys. Rev. B 92, 085125 (2015)

MA 36.9 Wed 17:30 HSZ 101

Enhanced indirect exchange interactions in the presence of circular potentials in graphene — •OZGUR CAKIR and AHMET UTKU CANBOLAT — Izmir Institute of Technology, Physics Department, 35430, Urla, Izmir, TURKEY

We study indirect exchange interaction between two magnetic impurities in pristine graphene in the presence of a circular potential. In bulk graphene structures indirect exchange interaction, also known as RKKY (Ruderman-Kittel-Kasuya-Yosida) interaction, shows a power-law decay with distance for both doped and undoped cases. Here we show that under a circular electric potential quasibound states lead to enhanced RKKY interactions between magnetic moments located in the vicinity of the potential well. It is shown that the strength of the potential well and Fermi energy can be tuned to create enhanced long ranged RKKY interactions. We show that when the Fermi level lies at the quasibound state energy, the scattering processes between the states of the same chirality dominate over the other scattering channels and this leads to a predominantly ferromagnetic, enhanced interaction between the impurities at long distances. The predicted effect can enable electrical control of RKKY interactions in graphene or other two-dimensional materials.

MA 36.10 Wed 17:45 HSZ 101

Ferromagnetism in graphene — •Mukul Kabir — Department of Physics, Indian Institute of Science Education and Research, Pune 411008, India

Metal-free magnetism in graphene has remained a subject of intense research, and many research groups have invested in understanding the roles of doping, structural defects and edge structure in finite-sized nano-flakes. However, a robust long-range magnetic order has remained elusive. In this context, recently nitrogen-doped graphene is experimentally proposed to be a promising candidate, however, the Curie temperature remains controversial. The corresponding exchange mechanism endures unclear and is essential to tune further and manipulate magnetism. In this talk, within the first-principles calculations, we will systematically discuss the local moment formation and the concurrent interaction between various defect complexes. The importance of adatom diffusion on the differential defect abundance will be elaborated. We will establish that the direct exchange mechanism between the delocalized magnetic moment originating from the π-electron at the prevalent triazine complex to be responsible for the observed ferromagnetism.

MA 37: Frustrated Magnets - Strong Spin-Orbit Coupling 2 (joint session TT/MA)

Time: Wednesday 15:00–17:45 Location: HSZ 304

MA 37.1 Wed 15:00 HSZ 304

Magnetic frustration in fcc lattices — •Veronika Fritsch[1], Christina Baumeister[1], F. Maximilian Wolf[1], Johanna Oefele[1], Jens-Uwe Hoffmann[2], Manfred Reehuis[2], and Oliver Stockert[3] — [1]EP 6, Electronic Correlations and Magnetism, Augsburg University, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

A face-centered cubic (fcc) lattice is inherently prone to magnetic frustration, since it is build from a network of edge-sharing tetrahedra. Up to now most studies were performed on insulating systems. We have investigated various metallic systems with neutron diffraction experiments, where the magnetic Ho-ions form an fcc lattice: $HoInCu_4$ and $HoCdCu_4$ [1] as well as $HoInAg_2$ and $HoInAu_2$. All compounds exhibit long-range magnetic order with different propagation vectors, which can be understood within a simple J_1/J_2 model [2]. Furthermore we found diffuse scattering dependent on the degree of frustration of the samples.

[1] V. Fritsch *et al.*, arXiv:1907.09885 [cond-mat.str-el]
[2] P. W. Anderson, Phys. Rev. **79**, 705 (1950).

MA 37.2 Wed 15:15 HSZ 304

The evolution of magnetic frustration in $HoInAg_{2-x}Au_x$ — •Johanna Oefele[1], Oliver Stockert[2], Philipp Gegenwart[1], and Veronika Fritsch[1] — [1]EP6, Electronic Correlations and Magnetism, Augsburg University, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

While the intermetallic compounds $HoInAg_2$ and $HoInAu_2$ share the same face-centered cubic crystal structure and are isoelectronic, the magnetic properties significantly deviate from each other. $HoInAg_2$ is strongly frustrated as evidenced by its thermodynamic properties and a large frustration parameter. In contrast the $HoInAu_2$ system shows no signs of magnetic frustration. In order to explore the transition from the frustrated to the non-frustrated system we synthesised the substitution series $HoInAg_{2-x}Au_x$.

In this talk I will present the crystal growth and the susceptibility, specific heat and the resistivity measurements on our polycrystalline samples. The effective paramagnetic moments extracted from the magnetic susceptibility coincide with the value expected for free Ho^{3+}. From the specific heat the entropy was calculated confirming the presence of magnetic frustration in $HoInAg_2$. With increasing substitution of Ag with Au the Néel temperature is monotonically increasing, while the frustration vanishes.

MA 37.3 Wed 15:30 HSZ 304

Short range spin ice type correlations of Kagome spin ice HoAgGe by diffuse neutron scattering — •Kan Zhao and Philipp Gegenwart — Experimentalphysik VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86159 Augsburg, Germany

Spin ices are exotic phases of matter characterized by frustrated spins obeying local ice rules that minimize the number of spatially isolated magnetic monopoles, in analogy with the electric dipoles in water ice. In two dimensions, one can similarly define ice rules for in-plane Ising-like spins arranged on a kagome lattice, which require each triangle plaquette to have a single monopole, and can lead to a variety of unique orders and excitations.

With P-62m structure, Ho sites of HoAgGe in the ab plane form a distorted kagome lattice. According to magnetometry, thermodynamic measurements, elastic neutron scattering and Monte Carlo simulations, we establish HoAgGe as the unique crystalline system to realize the kagome spin ice state [1].

The short range spin ice type correlations, have been predicted as one characteristic feature of classical kagome spin ice model. Thus, we conducted the diffuse scattering for HoAgGe above the long range magnetic order temperature. And clear diffuse scattering pattern is obtained, which is consistent with that of Monte Carlo simulations based on a classical spin model consisting of Ising-like in-plane spins on the 2D distorted kagome lattice of HoAgGe [1].

[1] Zhao, Kan et al. Submitted (2018)

MA 37.4 Wed 15:45 HSZ 304

New phases in the Shastry-Sutherland compound NdB_4 discovered by high-resolution dilatometry — •Rahel Ohlendorf[1], Sven Spachmann[1], Daniel Brunt[2], Oleg Petrenko[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Department of Physics, University of Warwick, UK

We report detailed thermal expansion and magnetostriction studies on NdB_4 single crystals in magnetic fields up to 15 T. The system can be mapped on a Shastry-Sutherland model implying magnetically frustrated orthogonal dimers of Nd-moments. Accordingly, a sequence of unusual magnetic phases has been reported [1]. At $B = 0$ T these phases are associated with the evolution of antiferromagnetic (afm) order at $T_1 = 17.2$ K and two incommensurate afm phases at $T_2 = 7.0$ K and $T_3 = 4.8$ K. All transitions are associated with pronounced anomalies in the thermal expansion coefficients which enables studying the phase boundaries in external magnetic fields, here applied along the crystallographic [001]- and [110]-axis, respectively. Our data confirm previously reported phase boundaries and show, e.g., that the nature of the phase transition $T_2(B)$ changes from continuous to discontinuous. In addition, for each field direction our data evidence novel phases not reported before. The phase diagram is discussed based on the anomalies in the thermal expansion and magnetostriction data and the respective uniaxial pressure dependencies.

[1] Ryuta Watanuki et al 2009 J. Phys.: Conf. Ser. 150 042229

15 min. break.

MA 37.5 Wed 16:15 HSZ 304

Energy dynamics in the Kitaev quantum spin liquid at finite temperature and momentum — •Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, D-38106, Braunschweig, Germany

The role of finite temperature and momentum in the energy dynamics of the two-dimensional Kitaev spin-model on the honeycomb lattice are studied. Fractionalization of magnetic moments into mobile Majorana matter and a static $\mathbb{Z}_2$ gauge field lead to a continuum of energy density modes comprising two channels. Thermal flux excitations, which act as an emergent disorder, strongly affect the dynamical energy susceptibility. Above the flux proliferation temperature, coherent energy propagation is modified into a quasi hydrodynamic density relaxation, the temperature and momentum dependence of which is analyzed. Results from the low-temperature homogeneous gauge and a mean-field treatment of thermal gauge fluctuations, valid at intermediate and high temperatures are considered.

MA 37.6 Wed 16:30 HSZ 304

Raman spectrum of two particle excitations in the Kitaev-Heisenberg bilayer — •Erik Wagner and Wolfram Brenig — Institute for Theoretical Physics, Technical UniversityBraunschweig, Braunschweig, Germany

We study the Raman response of a honeycomb Kitaev spin-model with (an-)isotropic intralayer exchange $J_{x,y,z}$, coupled by additional interlayer Heisenberg exchange J to form a bilayer. Starting from the limit of decoupled dimers we use a perturbative continuous unitary transformation (pCUT), based on the flow equation method, to perform series expansion on the Hamiltonian and the Raman operator to analyze the spectrum. In particular we consider the groundstate energy and one particle dispersion up to 9th order in $J_{x,y,z}$ as well as the two particle interactions and spectrum up to 8th order. Results for the Raman response as well as (anti-)bound states will be presented versus anisotropy and for various bilayer-stackings.

MA 37.7 Wed 16:45 HSZ 304

Excitonic Magnetism at the intersection of Spin-orbit coupling and crystal-field splitting — Teresa Feldmaier[1], Pascal Strobel[1], Michael Schmid[1,2], Philipp Hansmann[3], and •Maria Daghofer[1] — [1]FMQ, Universität Stuttgart, Germany — [2]IQST, Stuttgart and Ulm, Germany — [3]MPI-CPfS, Dresden, Germany

Excitonic magnetism involving superpositions of singlet and triplet states is expected to arise for two holes in strongly correlated and spin-orbit coupled t_{2g} orbitals. However, uncontested material examples for its realization are rare. Applying the Variational Cluster Approach to the square lattice, we find for weak spin-orbit coupling stripy spin antiferromagnetism combined with stripy orbital order without a crystal field and checkerboard spin antiferromagnetism when crystal field favors the xy orbital. Strong spin-orbit coupling leads to excitonic antiferromagnetism that can coexist with substantial orbital polarization. We then address the specific example of Ca_2RuO_4 using *ab initio* modeling and conclude it to realize excitonic magnetism despite its pronounced orbital polarization.

MA 37.8 Wed 17:00 HSZ 304

Influence of spin-orbit coupling onto thermodynamic and dynamic properties of d^5- and d^4-systems — •Jan Lotze and Maria Daghofer — University of Stuttgart, Functional Matter and Quantum Technologies, Pfaffenwaldring 57, 70569 Stuttgart

We investigate the two-dimensional, spin-orbit coupled, three-band Hubbard model in the d^5 and d^4 configuration at finite temperature by means of the variational cluster approximation. Thermodynamic (magnetization, specific heat) and dynamic (DOS, spectral function) properties are presented. We investigate the influence of cluster size and symmetry on the Néel temperature T_{N} and on spectra.

We find that the DOS of the d^5-system supports the picture of a system between clear Slater- and Mott-scenarios and that the orbital degrees of freedom remain quenched even for temperatures above T_{N}. The d^4-system is already insulating at very high temperatures. Both a crystal field and spin-orbit coupling (SOC) lead to antiferromagnetic order at low temperature, but the finite-T properties differ markedly: Without SOC, the onsite states defining the local moments do not change substantially with $T > T_{\mathrm{N}}$. In the presence of SOC, in contrast, weight in the onsite singlet favored by SOC increases markedly when T is lowered towards T_{N}. This is in agreement with X-ray reporting changes to the orbital character at temperatures above T_{N}.

MA 37.9 Wed 17:15 HSZ 304

Nonlinear spin-wave theory for the Heisenberg-Kitaev model in a magnetic field — •Pedro M. Cônsoli[1,2], Lukas Janssen[2], Matthias Vojta[2], and Eric C. Andrade[1] — [1]Instituto de Física de São Carlos, Universidade de São Paulo, São Carlos, Brazil — [2]Institut für Theoretische Physik, TU Dresden, Dresden, Germany

The exact solution of Kitaev's honeycomb model and the ensuing realization that it gives rise to chiral Majorana edge modes in a small and properly oriented magnetic field sparked an intense search for a physical mechanism capable of replicating such a system in real materials. This missing link was provided by Khaliullin and Jackeli, who showed that an interplay between crystal field effects and strong spin-orbit coupling originates the Kitaev interaction along with a Heisenberg exchange in a class of Mott insulators. Hence, the Heisenberg-Kitaev Hamiltonian became a minimal model to describe Kitaev materials and was subsequently studied in much detail. Still, several questions related to effects of external perturbations remain unanswered.

Here, we discuss the physics of the Heisenberg-Kitaev model in the presence of a magnetic field applied along two different directions: [100] and [111], for which an intricate classical phase diagram has been reported. In both settings, we employ spin-wave theory for a number of ordered phases to compute magnetization curves and phase boundaries in next-to-leading order in $1/S$, with S being the spin size. In this way, we show that quantum corrections substantially modify the phase diagram. Finally, we compare our spin-wave theory results to exact diagonalization calculations performed on a 24-site cluster.

MA 37.10 Wed 17:30 HSZ 304

How spin-orbital entanglement depends on the spin-orbit coupling in a Mott insulator — •Dorota Gotfryd[1,2], Ekaterina M. Paerschke[3,4], Andrzej M. Oles[2,5], and Krzysztof Wohlfeld[1] — [1]Faculty of Physics, University of Warsaw, Pasteura 5, PL-02093 Warsaw, Poland — [2]Institute of Physics, Jagiellonian University, Lojasiewicza 11, PL-30348 Krakow, Poland — [3]Department of Physics, University of Alabama at Birmingham, Birmingham, Alabama 35294, USA — [4]Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [5]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

The concept of spin-orbital entanglement plays a crucial role in understanding various phases and exotic ground states in a broad class of materials, including orbitally ordered materials and spin liquids. We investigate how this entanglement depends on the value of the relativistic spin-orbit coupling. To this end, we numerically diagonalise spin-orbital model with the 'Kugel-Khomskii' exchange supplemented by the on-site spin-orbit coupling. While for small spin-orbit coupling the ground state resembles the vanishing spin-orbit coupling case, for large spin-orbit coupling it can either show negligible spin-orbital entanglement or can evolve to a highly entangled state with completely distinct properties, described by an effective model. The presented range of spin-orbit coupling is relevant not only for 5d but also for 3d or some of the 4d transition metal oxides.

MA 38: Multiferroics and Magnetoelectric Coupling II (joint session MA/KFM)

Time: Wednesday 15:00–17:00 Location: HSZ 401

MA 38.1 Wed 15:00 HSZ 401

Switching of magnetoelectric states in Y-type hexaferrite single crystals — •Vilmos Kocsis[1], Taro Nakajima[1], Masaaki Matsuda[2], Akiko Kikkawa[1], Yoshio Kaneko[1], Junya Takashima[1,3], Kazuhisa Kakurai[1,4], Taka-hisa Arima[1,5], Yusuke Tokunaga[1,5], Yoshinori Tokura[1,6], and Yasujiro Taguchi[1] — [1]RIKEN CEMS, Wako-shi, Japan — [2]Oak Ridge National Laboratory, Tennessee, USA — [3]Venture Lab TOKYO, Tokyo, Japan — [4]CROSS, Tokai, Japan — [5]Department of Advanced Materials Science, University of Tokyo, Kashiwa Japan — [6]Tokyo College and Department of Applied Physics, University of Tokyo, Tokyo, Japan

In Y-type hexaferrites, magnetic interactions result in a complex phase diagram with non-collinear magnetic phases. The magnetoelectric (ME) properties are mainly dominated by a multiferroic FE3 phase [1,2]. The FE3 phase has been observed both as a metastable and stable phase close to room temperatures [3,4,5] and offers an ideal candidate to study the stability of ME phases and ME states. Here we explore the direct and converse ME effects in Y-type hexaferrites with different Sr doping levels. We demonstrate the isothermal switching between ME states, and discuss these new results as a possible way to measure the stability of the ME state in multiferroic materials. [1] T. Kimura, Ann. Rev. Condens. Matter Phys. 3, 93-110 (2012) [2] T. Kimura et. al., PRL 94, 137201 (2005) [3] S. Hirose et. al., APL 104, 022907 (2014) [4] T. Nakajima et. al., PRB 94 195154 (2016) [5] V. Kocsis et. al., Nat. Comm. 10, 1247 (2019)

MA 38.2 Wed 15:15 HSZ 401

Low-frequency magnetic resonances of the polar ferrimagnet Mn2Mo3O8 — •Dávid Szaller[1], Lukas Weymann[1], Alexey Shuvaev[1], Andrei Pimenov[1], Johan Viirok[2], Urmas Nagel[2], Toomas Room[2], Sándor Bordács[3], Krisztián Szász[3], Vladimir Tsurkan[4], and István Kézsmárki[4] — [1]Institute of Solis State Physics, TU Wien — [2]National Institute of Chemical Physics and Biophysics, Tallinn — [3]Department of Physics, Budapest University of Technology and Economics — [4]Experimental Physics V, University of Augsburg

The polar M2Mo3O8 crystals with M=Fe,Co,Mn, exhibit various magnetic orders coupled to the electric polarization of the material. In the static limit, this magneto-electric coupling opens a new path for data storage[1], while in the dynamical range the spin-wave excitations offer a model system to study axion physics[2]. However, the microscopic description of the spin-wave resonances and the magneto-electric coupling in these material family is still an open task.

We followed the magnetic field dependence of the spin-wave resonances of the ferrimagnetic Mn2Mo3O8 in three magnetic phases by combining far-infrared optical spectroscopy and backward-wave oscillators. Both the observed resonance frequencies and the field dependence of the magnetization were quantitatively reproduced by a relative simple anisotropic two-sublattice antiferromagnetic model.

[1]Y. Wang et al, Sci. Rep. 5, 12268 (2015).

[2]T. Kurumaji et al, Phys. Rev. Lett. 119, 077206 (2017).

MA 38.3 Wed 15:30 HSZ 401

Signatures of electric dipoles in zig-zag spin chain β-TeVO$_4$ — Martina Dragičević[1], Željko Rapljenović[1], David Rivas Góngora[1], Mirta Herak[1], •Tomislav Ivek[1], Matej Pregelj[2], Andrej Zorko[2], Helmuth Berger[3], and Denis Arčon[2,4] — [1]Institute of Physics, Zagreb, Croatia — [2]Jožef Stefan Institute, Ljubljana, Slovenia — [3]Ecole polytechnique fédérale de Lausanne, Lausanne, Switzerland — [4]Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia

Even though non-composite magnetoelectric materials appear to be rare, one promising way to achieve magnetoelectric effect is through spiral magnetic orders which can break the space inversion symmetry and allow electric dipoles to form. In this work we present the dielectric response of single crystal quasi-1D quantum magnet β-TeVO$_4$ at low temperatures and in the presence of external magnetic field. This zig-zag spin chain system with frustrated anisotropic interactions has a complex phase diagram: at $T_{\rm N1} = 4.65\,$K the paramagnetic phase gives way to an incommensurate spin-density wave; below $T_{\rm N2} = 3.28\,$K a superposition of two spin-density waves is observed with differing wave vectors, the so-called spin stripe phase; finally, at the low temperature of $T_{\rm N3} = 2.28\,$K their two wave vectors coincide and a vector chiral ground state is established. Most interestingly, at $T_{\rm N3}$ there are tantalizing experimental indications of emergent electric dipoles. The magnetic phase diagram will be discussed in the context of dielectric properties and of ground state as a potentially multiferroic phase.

MA 38.4 Wed 15:45 HSZ 401

In-plane magnetoelectric response in bilayer graphene — •Paul Wenk[1], Michael Kammermeier[2], and Ulrich Zülicke[2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]School of Chemical and Physical Sciences and MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand

A graphene bilayer shows an unusual magnetoelectric response whose magnitude is controlled by the valley-isospin density, making it possible to link magnetoelectric behavior to valleytronics. Complementary to previous studies, we consider the effect of static homogeneous electric and magnetic fields that are oriented parallel to the bilayer's plane. Starting from a tight-binding description and using quasidegenerate perturbation theory, the low-energy Hamiltonian is derived, including all relevant magnetoelectric terms whose prefactors are expressed in terms of tight-binding parameters. We confirm the existence of an expected axion-type pseudoscalar term, which turns out to have the same sign and about twice the magnitude of the previously obtained out-of-plane counterpart. Additionally, small anisotropic corrections to the magnetoelectric tensor are found that are fundamentally related to the skew interlayer hopping parameter γ_4. We discuss possible ways to identify magnetoelectric effects by distinctive features in the optical conductivity.

[PRB **100**, 075421 (2019)]

MA 38.5 Wed 16:00 HSZ 401

In-situ switching of the magnetoelectric domain states in the cubic spinel Co_3O_4 — •Maximilian Winkler, Somnath Ghara, Korbinian Geirhos, Peter Lunkenheimer, Stephan Krohns, Vladimir Tsurkan, and István Kézsmárki — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

We report a strong linear magnetoelectric effect in the collinear antiferromagnetic state of Co_3O_4 single crystals. Co_3O_4 crystallizes in the cubic spinel structure, with magnetic Co^{2+} at the A-sites, tetrahedrally surrounded by oxygen, and non-magnetic Co^{3+} at the B-sites in an octahedral environment [1]. In this work, we investigate all components of the magnetoelectric tensor and found that the largest value of is $\alpha = 14$ ps/m. We showed that the magnetoelectric monodomain state can be obtained by magnetoelectric poling across the Néel-temperature, $T_N = 30$ K. For the mono-domain state the sign of α depends on the sign of the product of the external electric and magnetic fields, E and H. We also demonstrated, that after the magnetoelectric poling below T_N the magnetoelectric domain state can be controlled in-situ by reversing either the external electric or magnetic field. The dynamics of this switching process leads to a deeper understanding of the linear magnetoelectric coupling in Co_3O_4.

[1] W. Roth, *J. Phys. Chem. Solids* **25**, 1-10 (1964)

MA 38.6 Wed 16:15 HSZ 401

Magnetoelectricity in Itinerant-Electron Paramagnets, Ferromagnets and Antiferromagnets — •Roland Winkler[1,2,3] and Ulrich Zülicke[4,2] — [1]Physics, Northern Illinois University, USA — [2]Materials Science Division, Argonne National Laboratory, USA — [3]Materials Science and Engineering, University of Illinois at Urbana-Champaign, USA — [4]School of Chemical and Physical Sciences and MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, New Zealand

We present a detailed theory for magnetoelectricity in itinerant-electron paramagnets, ferromagnets and antiferromagnets, whereby an electric field can induce a magnetization and a magnetic field can induce a polarization. Accurate numerical calculations are complementd by analytical models that provide a detailed microscopic understanding of magnetoelectricity in itinerant-electron systems. Our realistic calculations suggest that an electrically induced magnetization can be as large as one Bohr magneton per charge carrier.

This work was supported by the NSF under Grant No. DMR-1310199. Research at UIUC was supported by the Illinois MRSEC, NSF Grant No. DMR-1720633. Work at Argonne was supported by DOE BES under Contract No. DE-AC02-06CH11357.

MA 38.7 Wed 16:30 HSZ 401

Voltage-controlled on switching and manipulation of magnetization via redox transformation of beta-FeOOH nanoplatelets — •Martin Nichterwitz[1,2], Sabine Neitsch[1], Stefan Röher[1], Daniel Wolf[1], Kornelius Nielsch[1,2], and Karin Leistner[1] — [1]IFW Dresden, Germany — [2]TU Dresden, Germany

Voltage control of magnetism by ionic approaches, such as the metal/metal oxide transformation in gated architectures, presents a promising pathway to low-power magnetic devices or magnetic actuation. Such magneto-ionic manipulation has been reported mainly for ultrathin films and nanoporous metal alloy structures so far.

We investigate electrodeposited porous beta-FeOOH nanoplatelets as starting material, known as active material from catalysis research. The FeOOH is polarized in 1M LiOH solution at room temperature. The voltage-induced structural and morphological changes are probed and correlated to the magnetic changes measured in an in situ anomalous Hall effect setup. This approach, starting from paramagnetic FeOOH, enables complete and non-volatile ON switching of ferromagnetic layers at a low voltage and large reversible magneto-ionic effects.[1] During the first reduction step, we transform FeOOH into a rough granular Fe layer. This high surface Fe layer is then switched reversibly via a redox transformation. As a result, large voltage-induced changes in magnetization are achieved, which exceed those obtained for sputtered Fe films and Fe nanoislands.[2]

[1] Nichterwitz et al., J. Phys. D (2019), accepted;
[2] Duschek et al., J. Mater. Chm. C 6 (2018) 8411

MA 38.8 Wed 16:45 HSZ 401

Magneto-ionic tunable hysteresis, magnetic domains and exchange bias in ironoxide/iron surface layers — •Jonas Zehner[1], Rico Huhnstock[2], Steffen Oswald[1], Sebastian Schneider[1], Ivan Soldatov[1], Sebastian Fähler[1], Rudolf Schäfer[1], Arno Ehresmann[2], Kornelius Nielsch[1], Dennis Holzinger[2], and Karin Leistner[1] — [1]IFW Dresden — [2]Uni Kassel, Institut für Physik und CINSaT

The ubiquity and rise in the use of electronic devices demands low power operation modes. Voltage assisted ionic displacement and electrochemical processes offer large magnetic changes at room temperature. This so called magneto-ionic (MI) control shows promising characteristics to enable energy efficient spintronics, actuation and neuromorphic computing. In the current study, MI effects on coercivity and exchange bias (EB) are demonstrated for sputter deposited and natively oxidized FeOx/Fe films of up to 13 nm in thickness. In FeOx/Fe films, the uniaxial anisotropy constant Ku increases upon an electrochemical transformation of the oxide layer to metal iron. At the same time, consistent with the anisotropy change, the equilibrium magnetic domain size increases. This effect enables voltage-induced 180° magnetization switching. In a next step, this tunable FeOx/Fe layer is combined with an underlying antiferromagnet. Non-volatile and reversible changes in the EB are achieved this way. The mechanism is revealed via X-ray photoemission spectroscopy and links the observed changes to an increase in the Fe layer thickness. These results are exciting for designing EB systems and magneto-electric devices in general.

MA 39: Correlation Theory II

Time: Wednesday 15:00–16:00 Location: HSZ 403

MA 39.1 Wed 15:00 HSZ 403

Magnetism of the rare-earth elements, have we really understood everything ? — •olle Eriksson — Uppsala University, Uppsala, Sweden — Örebro University, Örebro, Sweden

The magnetic properties of rare-earth elements will be described in this talk, with focus on how well electronic structure theory is able to reproduce observations. In this presentation, it is described how information from electronic structure calculations can be mapped to a low energy effective spin-Hamiltonian, and the accuracy of this Hamiltonian is tested against known observables like magnon dispersion and ordering temperature. Recent results suggest that the magnetic configuration of light rare-earths is considerably more complex than previously assumed. These complex magnetic structures are analyzed from an electronic structure point of view. It is demonstrated that properties hitherto unknown among any magnetic system, may indeed be observed in the light rare-earths.

MA 39.2 Wed 15:15 HSZ 403

First principles calculations and Monte Carlo simulations of half-metallic $CaCu_3Fe_3Re_2O_{12}$ quadruple perovskite — •Duo Wang[1], Saurabh Ghosh[2], and Biplab Sanyal[1] — [1]Uppsala University, Uppsala, Sweden — [2]SRM University, Chennai, India

Materials that have high spin-polarized conduction electrons at room temperature are very important for spintronic developments. Wentin Chen *et al.* have synthesized the quadruple perovskite $CaCu_3Fe_3Re_2O_{12}$, which shows half-metallic electronic structure, large magnetization and very high Curie temperature (up to 560K). We have performed density functional calculations on the ground state structure $(CaCu^{2+}(\uparrow)_3Fe^{3+}(\uparrow)_2Re^{5+}(\downarrow)_2O_{12})$, and calculated interatomic exchange interactions with the Full-Potential Linear Muffin-Tin Orbital (FP-LMTO) method. We find that both J_{Re-Cu} and J_{Re-Fe} show strong antiferromagnetic coupling along with ferromagnetic coupling between Fe moments. This is consistent with ferrimagnetic nature of A_2FeReO_6 (A=Ca, Sr and Ba, respectively) double perovskite that the high Curie temperature indicate strong antiferromagnetic couplings. We also performed Monte Carlo simulations using the exchange parameters obtained from the FP-LMTO method. The magnetic transition temperature is found to be 295K. Besides that, the size of A-site cation will affect the crystal structure, magnetism, exchange interactions and also magnetic ordering temperature. Calculations to replace A-site atom (Ca) are ongoing.

MA 39.3 Wed 15:30 HSZ 403

Magnetic interactions in the honeycomb Kitaev-Heisenberg systems H3LiIr2O6 and Cu2IrO3 by ab initio quantum chemical methods — •Mohamed Eldeeb[1], Ravi Yadav[1], Satoshi Nishimoto[1,2], Jeroen van den Brink[1,2], and Liviu Hozoi[1] — [1]Institute for Theoretical Solid State Physics, Leibniz IFW Dresden, Helmholtzstr. 20, 01069, Dresden, Germany — [2]Department of Physics, Technical University Dresden, Helmholtzstraße 10, D-01069 Dresden, Germany

The magnetic interactions in honeycomb iridium oxide compounds are studied using quantum chemical wavefunction-based methods. Mapping the results onto the corresponding effective spin model shows the crucial dependence of the anisotropic magnetic couplings, in particular Kitaev exchange, on the precise position of inter-layer species and on additional geometrical factors such as Ir-O-Ir bond angles and Ir-O bond lengths. While the latter define the actual superexchange path between magnetic centers, the former may come into play through strong out-of-plane polarization of ligand 2p orbitals mediating intersite hopping [1,2]. (1)R. Yadav, R. Ray, M. S. Eldeeb, S. Nishimoto, L. Hozoi, and J. van den Brink, Phys. Rev. Lett. 121, 197203 (2018). (2) R. Yadav, M. S. Eldeeb, R. Ray, S. Aswartham, M. I.Sturza, S. Nishimoto, J. van den Brink, and L. Hozoi, Chem. Sci. 10, 1866 (2019).

MA 39.4 Wed 15:45 HSZ 403

Quantum Electrodynamical Bloch Theory with Homogeneous Magnetic Fields — •Vasil Rokaj, Markus Penz, Michael Sentef, Michael Ruggenthaler, and Angel Rubio — Max Planck Institute for the Structure & Dynamics of Matter, Hamburg, Germany

Probing electronic properties of periodic systems by homogeneous magnetic fields has unravelled fundamental new phenomena in condensed matter physics. Much theoretical work has been devoted to describe those systems in different regimes, still a general first principles modeling of such fundamental effects is lacking. Here we propose a solution to the problem of Bloch electrons in a homogeneous magnetic field by including the quantum fluctuations of the photon field. A generalized quantum electrodynamical (QED) Bloch theory from first principles is presented. As an application, we show how the well-known Landau physics is modified by the photon field and that Landau polaritons emerge. Moreover, for a 2D solid in a perpendicular magnetic field, in the limit of vanishing quantum fluctuations, we recover the standard results of solid-state physics: the fractal spectrum of the Hofstadter butterfly. Further generalizations and modifications of the Hofstadter butterfly will be presented for 2D materials like graphene and Moire superlattices which are of current experimental interest.

[1]V.Rokaj et al. Phys. Rev. Lett. 123, 047202 (2019)

MA 40: Skyrmions III (joint session MA/TT)

Time: Wednesday 15:00–18:30 Location: POT 6

MA 40.1 Wed 15:00 POT 6

Noncommutative geometry and the anomalous Hall effect in chiral spin textures — •Fabian R. Lux[1], Frank Freimuth[1], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

We demonstrate that the anomalous Hall effect (AHE) in chiral magnetic textures can naturally be described in the language of Alain Connes' noncommutative geometry which provides it with a deep geometrical interpretation. For periodic magnetic structures, the formalism reduces to the well-known Kubo-Bastin equations, but its applicability extends to all aperiodic cases in general. Under the assumption of a slowly varying texture, we derive the first order correction to the conventional AHE which is linear in the gradients of the magnetization texture [1]. This chiral Hall effect is neither proportional to the net magnetization nor to the emergent magnetic field that is responsible for the topological Hall effect and thus introduces an interesting twist in the interpretation of experimental data.

We acknowledge funding from Deutsche Forschungsgemeinschaft (DFG) through SPP 2137 "Skyrmionics".

[1] F. R. Lux *et al.*, arXiv:1910.06147 (2019)

MA 40.2 Wed 15:15 POT 6

Magnetic force microscopy investigation of spin textures in the ferromagnetic semimetal Fe_2Sn_3 — •Markus Altthaler[1,2], Erik Lysne[2], Erik Roede[2], Mohamed Kassem[1], Vladimir Tsurkan[1], Lilian Prodan[1], Stephan Krohns[1], Dennis Meier[2], and István Kézsmárki[1] — [1]Universität Augsburg, Germany — [2]Norwegian University of Science and Technology (NTNU)

Recently, Fe_3Sn_2 has been reported to exhibit a giant anomalous Hall effect [1] as well as a topological electronic structure [2] and to host magnetic skyrmions [3]. Unlike common skyrmion hosts, this material has inversion symmetry, therefore, the skyrmions do not emerge due to the Dzyalohinskii-Moriya interaction. Z. Hou et al. [3] suggested that both uniaxial magnetic anisotropy competing with long-range dipolar forces and exchange frustration due to the Kagome lattice play a significant role in the formation of skyrmions at room temperature in this compound. Our goal was to specify in more detail the driving force of skyrmion formation. In MFM studies performed on the surface of bulk Fe_3Sn_2 crystals we did not find stripe domains, instead a dendrite pattern, which indicates the lack of magnetic spirals in bulk samples. On the other hand, we found stripe domains in thin lamellae in zero magnetic field which transform to a bubble (skyrmion) lattice in modest magnetic fields. This together with the thickness dependence of the spiral wavelength implies that the uniaxial anisotropy competing with dipolar interactions is the origin of modulated magnetic states in Fe_3Sn_2. [1] L. Ye et al., Nature **555** (2018), 638; [2] J.-X. Yin et al., Nature **562** (2018), 91; [3] Z. Hou et al., Adv. Mater. (2017), 1701144

MA 40.3 Wed 15:30 POT 6

Stability and dynamics of in-plane Skyrmions — •Venkata Krishna Bharadwaj[1], Ricardo Zarzuela[1], Kyoung-Whan Kim[2], Jairo Sinova[1,3], and Karin Everschor-Sitte[1] — [1]Johannes Gutenberg-University, Mainz — [2]Center for Spintronics, Korea Institute of Science and Technology, South Korea — [3]Institute of Physics Academy of Sciences of the Czech Republic, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

In this work [1] we analyze skyrmions in in-plane magnets. Through symmetry analysis, we offer possible material candidates to observe these skyrmions and also provide the phase diagram of such crystal systems. In addition, we determine their stability and properties, taking into account the crystal symmetries of the materials. Using micromagnetic simulations we show that in-plane skyrmions can be produced via two mechanisms, namely: i) the 'blowing bubbles' technique, i.e the creation of skyrmions due to current flow through constricted geometries and ii) shedding of skyrmions from a magnetic impurity driven by spin-transfer torques, analogues to their out-of-plane counterparts. Furthermore, we study the spin-orbit torques driven skyrmion dynamics both analytically and through micromagnetic simulations. Our results also indicate the possibility of designing the racetrack for in-plane skyrmions, which are promising candidates for memory applications.

[1]R. Zarzuela, V.K. Bharadwaj, K-W. Kim, J. Sinova, K. Everschor-Sitte, arXiv:1910.00987 (2019)

MA 40.4 Wed 15:45 POT 6

First-principles prediction of in-plane magnetic skyrmions: a topological spin-texture for high-storage density — •Flaviano José dos Santos, Markus Hoffmann, Manuel dos Santos Dias, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Magnetic skyrmions competitive in information technology should be small to allow a high storage density. However, the dipole-dipole interaction (DDI) effectively impedes the miniaturization of skyrmions embedded in thin films and multilayers with typically out-of-plane magnetization. We predict from first-principles the existence of in-plane magnetic skyrmions in a Co monolayer on W(110). The magnetization of Co exhibits an in-plane easy axis, a geometry in which the DDI contributes to reducing the size of such topological spin textures. We discuss the various properties of these particles and list the mechanisms causing their stabilization. Due to the in-plane easy axis of the magnetization, mirror symmetry is preserved enabling the existence of antiskyrmions being degenerate in energy with skyrmions. This makes Co/W(110) a strong candidate for prospective devices, such as skyrmion/antiskyrmion racetracks [3].

We acknowledge funding from EU Horizon 2020 via ERC-consolidator Grant No. 681405-DYNASORE and DARPA TEE program through grant MIPR (#HR0011831554) from DOI. — Refs.: [1] Vidal-Silva *et al.*, J. Magn. Magn. Mater. **443**, 116 (2017); [2] Büttner *et al.*, Sci. Rep. **8**, 4464 (2018); [3] Moon *et al.*, arXiv:1811.12552 (2018).

MA 40.5 Wed 16:00 POT 6

Skyrmion lattice formation — •Thomas Winkler, Jakub Zázvorka, Nico Kerber, Klaus Raab, Florian Dittrich, Yuqingh Ge, Peter Virnau, and Mathias Kläui — Johannes Gutenberg Universität Mainz, Staudinger Weg 7, 55128 Mainz

Magnetic skyrmions are highly interesting magnetic spin structures and potential candidates for next generation computing devices due to their topology based stability [1,2]. There has been much work on the individual static and dynamic properties of skyrmions. However, their collective behavior is not yet well explored in particular in multilayer stacks with interfacial DMI. We have stabilized a skyrmion lattice in a single stack of Ta(5)/Co20Fe60B20(0.9)/Ta(0.08)/MgO(2)/Ta(5), and found that statistical order parameters can be varied by a change of the In-plane field and the temperature. The 2d skyrmion ensemble typically forms a liquid phase, but we also observe the emergence of hexagonal order for high densities. Using experimentally obtained parameters, coarse-grained numerical simulations are performed by modelling skyrmions as repulsive soft disks [3] to explain the results.

[1] Finocchio, G., Büttner, F., Tomasello, R., Carpentieri, M. & Kläui, M. Magnetic skyrmions: from fundamental to applications. J. Phys. D. Appl. Phys. 49, 423001 (2016). [2] Fert, A., Reyren, N. & Cros, V. Magnetic skyrmions: advances in physics and potential applications. Nat. Rev. Mater. 2, 17031 (2017). [3] S. Kapfer, S., Krauth, W. Soft-disk melting: From liquid-hexatic coexistence to continuous transitions. Physical Review Letters 114, 035702 (2015)

MA 40.6 Wed 16:15 POT 6

The effects of disorder on hysteresis loops in chiral magnets — David Cortes[1], Marijan Beg[1], Hans Fangohr[1,2], Tom Lancaster[3], Peter Hatton[3], Thorsten Hesjedal[4], and •Ondrej Hovorka[1] — [1]University of Southampton, UK — [2]European XFEL GmbH, Schenefeld, Germany — [3]Durham University, UK — [4]Oxford University, UK

In this talk we investigate the effect of random pinning sites on magnetization behaviour in systems with Dzyaloshinskii-Moriya interaction (DMI). We consider a standard classical spin Hamiltonian with Heisenberg exchange and DMI energy terms, and model the disorder through statistical Gaussian distribution of anisotropy. We first develop a mean-field model which allows to compute systematically and efficiently the magnetisation versus field hysteresis loops for variable temperature, and can be used for computing qualitative thermodynamic phase diagrams to guide computationally costly Monte-Carlo simulations. We show that as the standard deviation of the anisotropy distribution increases, relative to the strength of exchange interaction and DMI, the nature of the reversal modes observed along a typical hysteresis loop changes in a certain temperature window. Namely, in 'clean' systems with narrow anisotropy distribution, the reversal proceeds through the appearance of skyrmion lattices at low external fields, while in 'dirty' systems with broad anisotropy distribution, the reversal is through the nucleation of individual or small groups of skyrmions. We systematically quantify this effect and discuss its broader implications for applications.

MA 40.7 Wed 16:30 POT 6

Tuning the topology flip of magnetic skyrmions by an in-plane magnetic field — Florian Muckel[1], Stephan von Malottki[2], Christian Holl[1], Benjamin Pestka[1], Marco Pratzer[1], Pavel F. Bessarab[3], Stefan Heinze[2], and •Markus Morgenstern[1] — [1]II. Institute of Physics B, RWTH Aachen University and JARA-FIT, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany — [3]University of Iceland, Reykjavík, Iceland and ITMO University, St. Petersburg, Russia

Topological protection of magnetic skyrmions on a discrete lattice manifests itself in an energy barrier that can be overcome by local heating, for example by a tunneling electron. Here we use spin polarized scanning tunneling microscopy at 7 K to probe the current induced collapse of magnetic skyrmions in the Pd/Fe bilayer on Ir(111) as a function of the in-plane magnetic field $B_{\|}$ .The collapse rate caused by single hot electrons is tuned by four orders of magnitude via $B_{\|}$. We aim a more detailed understanding of the skyrmion collapse mechanism by locally mapping the collapse rate and deduce a change from a radially symmetric shrinkage of the skyrmion [1] towards a zipper-like Chimera collapse mechanism predicted by theory [2].

[1] Bessarab et. al. Comp. Phys. Comm. 196, (2015). [2] Meyer et. al. Nat. Commun. 10, (2019)

15 min. break.

MA 40.8 Wed 17:00 POT 6

Observation of unusual magnetic response at topological defects in FeGe — •Mariia Stepanova[1,2], Erik Lysne[1,2], Peggy Schoenherr[3], Jan Masell[4], Laura Köhler[5], Achim Rosch[6], Naoya Kanazawa[7], Yoshinori Tokura[4,7], Markus Garst[5,8], Alireza Qaiumzadeh[2], Arne Brataas[2], and Dennis Meier[1,2] — [1]NTNU, Trondheim, Norway — [2]QuSpin, NTNU, Trondheim, Norway — [3]ETH Zurich, Zürich, Switzerland — [4]RIKEN, Wako, Japan — [5]Technische Universität Dresden, Dresden, Germany — [6]Universität zu Köln, Köln, Germany — [7]University of Tokyo, Tokyo, Japan — [8]Karlsruhe Institute of Technology, Karlsruhe, Germany

Lamellar textures do not just arise in liquid crystals and biological systems, they are also observed in helimagnets. Analogous to cholesteric liquid crystals, chiral magnets possess a periodic layered structure and form different types of non-trivial topological defects. Using magnetic force microscopy (MFM) on the near-room temperature helimagnet FeGe, we resolve disclinations and dislocations with nonzero topological winding number, as well as three fundamental types of helimagnetic domain walls. Interestingly, in addition to their non-trivial structure, all topological defects in FeGe exhibit an unusual MFM response, which is not observed in regions with perfect lamellar-like order. This magnetic signature is similar to the so-called "lines of flare" in cholesteric liquid crystals, suggesting local variations in magnetic susceptibility. We investigate the origin of the magnetic signature of the topological defects and discuss the possibility to use the local MFM response as a read-out signal in device applications.

MA 40.9 Wed 17:15 POT 6

Band structure tuning of a skyrmion lattice with giant topological Hall effect — •Leonie Spitz[2], Max Hirschberger[1], Shang Gao[1], Taro Nakajima[1], Christian Pfleiderer[2], Takahisa Arima[1,3], and Yoshinori Tokura[1] — [1]RIKEN Center for Emergent Matter Science, 2-1 Hirosawa, Wakoshi, Saitama 351-0198, Japan — [2]Physik-Department, Technical University of Munich, 85748 Garching, Germany — [3]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 for the centrosymmetric frustrated triangular lattice magnet Gd_2PdSi_3 [1]. In contrast to non-centrosymmetric compounds, the skyrmion spin-vortices reported for Gd_2PdSi_3 can not be stabilized by the Dzyaloshinskii-Moriya interaction, but rather by frustration and the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction [2-4]. The nanometer-scale size of the skyrmions in Gd_2PdSi_3 is a further novelty and may give rise to a very large emergent magnetic field B_{em}.

The project to be presented aims at a deeper understanding of the emergence of the giant topological Hall effect in Gd_2PdSi_3. In an extensive study we investigated the effect of isoelectronic doping on the topological Hall effect, the magnetic structure, and the band structure of the system.

[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] S. Hayami, et al., Phys. Rev. B 95, 224424 (2017)

MA 40.10 Wed 17:30 POT 6

Nanoscale magnetic resonance imaging at room temperature using single spins in diamond — •Tetyana Shalomayeva[1], Jianpei Geng[1], Qi-Chao Sun[1], Rainer Stöhr[1], Stuart Parkin[2], and Jörg Wrachtrup[1,3] — [1]3rd Institute of Physics, University of Stuttgart — [2]Max Planck Institute of Microstructure Physics — [3]Max Planck Institute for Solid State Research

Due to the significant development of compounds hosting skyrmions at ambient conditions [1] the need of the quantitative real-space imaging of the magnetic textures is high nowadays. As an atomic-sized magnetic field sensor we use the point lattice defect in diamond, which consists of carbon vacancy and substitutional nitrogen atom (NV centre). For the scanning probe experiments single NV centre is integrated into the monolithic nanopillar, which plays the role of the sharp end of the AFM tip.

In this contribution we demonstrate the scanning probe measurement of the magnetic helical structure on the surface of thin Mn1.4Pt0.9Pd0.1Sn lamella via off-axial fluorescence quenching at room temperature and further numerical extraction of B-field.

[1] A.K. Nayak et al. Nature 548, 561-566 (2017)

MA 40.11 Wed 17:45 POT 6

Real-Space Imaging of the low-temperature Skyrmion phase in Cu2OSeO3 by Magnetic-Force-Microscopy — •Gerald Malsch[1], Peter Milde[1,2], Dmytro Ivaneiko[1], Christian Pfleiderer[3], Helmuth Berger[4], and Lukas Eng[1,2] — [1]Institute of Applied Physic, TU Dresden, 01187 Dresden, Germany — [2]ct.qmat: Würzburg-Dresden Cluster of Excellence - EXC 2147, TU Dresden, Germany — [3]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [4]Institut de Physique de la Matière Complexe, EPFL, 1015 Lausanne, Switzerland

Both small-angle neutron scattering measurements (SANS) and theoretical calculations indicate that there might exist additional skyrmion phases in Cu2OSeO3 in addition to its high-temperature phase, found at very low temperatures (LT) and only for magnetic fields applied along the <100> direction. These phases are usually hidden beneath a metastable tilted conical phase, but can be revealed by modulating the applied magnetic field.

Here we present a Magnetic-Force-Microscopy (MFM) analysis monitoring this LT skyrmion phase in real space. We find the LT skyrmion lattice to nucleate in micrometer-sized domains that coexist with tilted conical domains during the annealing process. Moreover, individual skyrmion domains are rotated relative to each other, resulting exactly in the ring-shaped halo as measured by SANS or REXS on a multidomain Cu2OSeO3 crystal.

MA 40.12 Wed 18:00 POT 6

Magnetic anisotropy in the itinerant helimagnet MnSi —

•Schorsch Michael Sauther[1], Michelle Hollricher[1], Vivek Kumar[1], Andreas Bauer[1], Markus Garst[2], Dirk Grundler[3], Christian Pfleiderer[1], and Marc Andreas Wilde[1] — [1]Phys.-Dept. E51, TU München — [2]TFP, KIT, Karlsruhe — [3]LMGN, IMX, STI, EPF Lausanne

We report torque magnetometry in Manganese silicide (MnSi). In our experiments, we employ different implementations of cantilever magnetometry to measure the torque τ resulting from the anisotropic magnetization $\vec{M}_{\perp}$ of a high-quality, single-crystalline bulk sample of MnSi. The angular dependence of τ displays distinct oscillations with differently pronounced extrema im compliance with an effective Landau potential for the magnetization. This minimal model allows us to extract the anisotropy constant directly from the $\tau(\phi)$ curve. We study its dependence on field magnitude and temperature in the vicinity of the material's modulated phases and discuss our results in the context of complementary experiments [1,2].

[1] A. Bauer *et al.*, Phys. Rev. B **95**, 024429 (2017)
[2] T. Adams *et al.*, Phys. Rev. Lett. **121**, 187205 (2018)

MA 40.13 Wed 18:15 POT 6

Quantitative magnetic force microscopy investigation of magnetic features in the biskyrmion hosting hexagonal Mn33Ni33Ga33 magnet — •N. Puwenberg[1,2], C. F. Reiche[3], P. Devi[4], U. Burkhardt[4], C. Felser[4], M. Sharma[1,2], T. Mühl[1], and B. Büchner[1,2] — [1]IFW Dresden, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]University of Utah, Salt Lake City, USA — [4]MPI CPfS, Dresden, Germany

We present quantitative magnetic force microscopy maps and distance dependent force spectroscopy measurements of the potentially biskyrmion hosting compound Mn33Ni33Ga33 employing an in-house fabricated custom-designed force sensor. Our magnetic sensing element is based on an iron-filled carbon nanotube attached to the free end of a super-flexible cantilever. Using a high aspect ratio magnetic nanowire offers a well-defined magnetic moment with a monopole-like magnetic stray-field characteristics at the nanowire's end, enabling the opportunity to easily quantify the magnetic stray-field on the sample surface. Our measurements were conducted in a single pass non-contact hybrid imaging mode. It features a direct sensing of the perpendicular magnetic stray-field component by measuring the normal cantilever deflection whilst a tip-sample distance control is realized by exploiting an AC bias driven flexural cantilever oscillation. Furthermore, the distance-dependency of the magnetic field and field gradient measured in the vicinity of individual magnetic features is fitted to simple magnetic models to make predictions about feature type, size and extension into the bulk's perpendicular third dimension.

MA 41: Ferroics - Domains and Domain Walls (joint session KFM/MA)

Time: Wednesday 15:00–18:20 Location: TOE 317

MA 41.1 Wed 15:00 TOE 317

Ferroelectric Domain Structure In Hexagonal Yttrium Manganite Thin Films - A Phase Field Study — •Amadé Bortis, Manfred Fiebig, and Thomas Lottermoser — Department of Materials, ETH Zurich, Zurich, Switzerland

The topologically protected vortex domains in hexagonal rare-earth manganites exhibit rich physics, both from a fundamental and application point of view. In thin films, however, the nanoscale domain size has thus far hindered the experimental investigation of domain patterns - the existence of vortex domains remains elusive. Here, we use a phase-field model based on a known Landau expansion of the free energy and incorporate boundary conditions for a thin film. With this model, we investigate up to which thickness a thin films retains the bulk-like vortex-string network - closed loops of connected vortices. We simulate the evolution of the structural domains for different thicknesses. In the ultrathin regime, we find straight lines of vortices emerging perpendicular to the films surface, similar to stacked 2D vortex patterns. As the thickness increases, we find an intermediate regime where the vortex lines start bending and merging, while still not being connected into closed loops. Finally, the bulk-like vortex-strings are recovered for a thickness of about 50 unit cells. Our work shows an effective 2D to 3D transition in rare-earth manganite thin films, revealing the impact of confined dimensionality on the domain topology.

MA 41.2 Wed 15:20 TOE 317

Dielectric nonlinearity in 0.5($Ba_{0.7}Ca_{0.3}$)TiO_3–0.5Ba($Zr_{0.2}$ $Ti_{0.8}$)O_3 ferroelectric thin film capacitors — •Maximilian Becker[1,2], Claus Burkhardt[1], Reinhold Kleiner[2], and Dieter Koelle[2] — [1]NMI Natural and Medical Sciences Institute at the University of Tübingen, Reutlingen, Germany — [2]Physikalisches Institut and Center for Quantum Science (CQ) in LISA$^+$, University of Tübingen, Germany

We use the recently developed Rayleigh analysis based on impedance spectroscopy to investigate dielectric nonlinearity caused by irreversible motion of domain walls in lead-free ferroelectric 0.5($Ba_{0.7}Ca_{0.3}$)TiO_3–0.5Ba($Zr_{0.2}Ti_{0.8}$)O_3 (BCZT) thin films. Impedance spectra from 10 Hz to 1 MHz were collected at different excitation fields on pulsed laser deposited polycrystalline and epitaxial BCZT thin film capacitors. Rayleigh plots were created by fitting the measured complex impedance to an equivalent-circuit model containing the Rayleigh element. For a polycrystalline film, we observed nonlinear behavior in good agreement with the Rayleigh law at a threshold field $E_T \approx 55$ kV/cm with Rayleigh constant $\alpha' = 0.407 \pm 0.035$ cm/kV. For the epitaxial counterpart, we found Rayleigh-like behavior which is not in full agreement with the Rayleigh law at $E_T \approx 3.75$ kV/cm with $\alpha' = 1.836 \pm 0.031$ cm/kV, indicating a significantly higher domain wall mobility. Our results demonstrate the superiority of Rayleigh analysis based on impedance spectroscopy over the commonly used single-frequency approach.

This work was partly funded by the BMBF (Grant No. 13GW0123E).

MA 41.3 Wed 15:40 TOE 317

Soft modes and effective Hamiltonian for the antiferroelectric NaNbO3 — •Niloofar Hadaeghi and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

To understand the antiferroelectric(AFE) phase transition in prototype $NaNbO_3$, we carried out detailed symmetry analysis and first-principles calculations. The primary modes have been identified together with the coupling terms up to the fourth order based on symmetry. The corresponding energy landscape is obtained by constraint calculations with specific mode(s) frozen-in, and is further fitted to get the effective Hamiltonian. It is observed that there are three dominant modes for the AFE phase of $NaNbO_3$; R_5^-, T_2, and Δ_5. Our results reveal that it is not possible for the system to adopt the coupling of R_5^- and T_2 modes, since there is a strong mutual repulsion between them. However, coupling of both R_5^- and Δ_5, and T_2 and R_5^- are essential in the reduction of energy. Theses couplings are cooperative to stabilize the AFE phase. That is, the trilinear coupling is essential for the occurrence of the AFE phase. We also investigated the unfolded band structure to understand the effects of such soft modes on the electronic structure.

MA 41.4 Wed 16:00 TOE 317

Dimerized phases in IrTe2: phase diagram from a first-principles-derived model — Gabriele Saleh and •Sergey Artyukhin — Italian Institute of Technology, Genova, Italy

Materials with strong spin-orbit coupling have attracted recent interest due to their non-trivial magnetism and topological properties. IrTe2 combines some of the strongest spin-orbit-coupled cations and anions, and shows below 220 K a puzzling sequence of ordered phases with different patterns of short Ir-Ir bonds (dimers), some of which break the inversion symmetry. In spite of active efforts of the community, first principles simulations have struggled to describe the energetics of these phases, especially when the spin-orbit coupling is accounted for. Here we discuss a simplified model that captures dimer energetics, and use it to calculate the phase diagram and discuss the structure of domain walls. The choice of the model parameters is guided by first-principles simulations.

MA 41.5 Wed 16:20 TOE 317

Robust In-Plane Ferroelectricity in Ultrathin Epitaxial Au-

rivillius Films — •Elzbieta Gradauskaite[1], Marco Campanini[2], Banani Biswas[3], Christof W. Schneider[3], Manfred Fiebig[1], Marta D. Rossell[2], and Morgan Trassin[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Electron Microscopy Center, Empa, Switzerland — [3]LMX, Paul Scherrer Institut, Switzerland

Layered ferroelectrics exhibit functionalities beyond those of the classical ferroelectric perovskite compounds due to their highly anisotropic structure. Unfortunately, the layered architecture has been impeding their growth as single crystalline thin films, and thus their integration into oxide-electronic devices. We show that deposition of layered ferroelectric $Bi_5FeTi_3O_{15}$ (BFTO) thin films on a lattice-matching $NdGaO_3$ (001)-oriented orthorhombic substrate supports the epitaxial single-crystal form of this Aurivillius compound. Layer-by-layer growth is demonstrated, permitting in-situ control of thickness with sub-unit-cell accuracy and resulting in atomically flat surfaces. The achievement of twin-free films significantly enhances their uniaxial ferroelectric properties. In the ultrathin regime, such films exhibit in-plane polarization with a periodic arrangement of ferroelectric domains, which, in conjunction with uniaxial ferroelectric anisotropy, results in nominally charged domain walls. Hysteresis measurements reveal a remnant polarization of 16.5 μC cm^{-2} with a remarkable endurance after 10^{10} switching cycles. The uniaxial in-plane ferroelectricity of Aurivillius thin films breaks new ground for alternative device paradigms less susceptible to the depolarizing-field effects.

20 min. break

MA 41.6 Wed 17:00 TOE 317

Ferroelectric domain wall imaging by focused ion beam

— •Erik Roede[1], Aleksander Mosberg[1], Donald Evans[1], Theodor Holstad[1], Zewu Yan[2], Edith Bourret[3], Antonius van Helvoort[1], and Dennis Meier[1] — [1]NTNU, Trondheim, Norway — [2]ETH, Zurich, Switzerland — [3]Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Charged ferroelectric domain walls (DWs) have received much attention for their functional properties and potential applications [1]. The orientation of a DW relative to the ferroelectric polarization determines the charge state and electronic properties of the wall. Therefore, the propagation of DWs through a crystal has drastic effects on the properties measured at the surface. Still, research on DWs has so far been dominated by surface techniques.

In this work, we introduce the use of focused ion beam (FIB) techniques [2] for 3D domain and DW imaging in ErMnO3[3] with nanoscale resolution. This enables relating the measured surface properties to the 3D domain wall geometry, enabling a move towards a comprehensive knowledge of the intrinsic properties of charged ferroelectric domain walls and their application in future nanoelectronic devices.

[1] D. Meier et al., Nature Materials, 11, 284-288 (2012) [2] A. Mosberg et al., Appl. Phys. Lett. 115, 122901 (2019) [3] Z. Yan et al., J. Cryst. Growth, 409, 75-79 (2015)

MA 41.7 Wed 17:20 TOE 317

Functional bubble domains in ferroelectric superlattices

— •Anna Grünebohm[1] and Claude Ederer[2] — [1]ICAMS, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Materials Theory, ETH Zürich, 8093 Zürich, Switzerland

In this contribution we revisite the phase diagram of $BaTiO_3$–$SrTiO_3$ superlattices by means of ab initio based molecular dynamics simulations [1]. We discuss the stabilization of domain walls by epitaxial strain and the interplay of depolarization and anisotropy energy. Excitingly, transitions between stripe and bubble domains can be induced by an electrical field in close analogy to stray-field stabilized skyrmions in magnetic films. The local and global properties of the superlattices differ considerably in the vicinity of this transition. Thus exceptional functional responses such as negative capacitance may be realized.

[1] T. Nishimatsu et al., Phys. Rev. B **78**, 104104 (2008).

MA 41.8 Wed 17:40 TOE 317

Tracing domain formation in ferroelectric PZT films in-situ

— •Martin Sarott, Manfred Fiebig, and Morgan Trassin — Department of Materials, ETH Zurich, Switzerland

The pronounced impact of growth conditions on the formation of domains in ferroelectric thin films obstructs the effective design of devices based on ferroelectrics that require controlled polarization states and deterministic switching dynamics. Here, we overcome this notorious difficulty by tracking in-situ, during growth, the emergence of domains in ultrathin ferroelectric layers. We use a combination of in-situ optical second harmonic generation (ISHG) and reflection high energy electron diffraction to directly observe the formation of in-plane oriented a-domains in an otherwise c-domain matrix in technologically relevant PZT films. By monitoring ISHG, we correlate the signal to the domain structure and identify a signature of mixed in-plane/out-of-plane domain patterns. Furthermore, we reveal the impact of epitaxial strain on the emergence of a-domains in a c-domain matrix. Our in-situ approach allows us to disentangle the influence of various growth parameters on the domain structure and thus enables the design of thin films with predefined domain states for reliable ferroelectric properties in the ultrathin regime.

MA 41.9 Wed 18:00 TOE 317

Photovoltage from ferroelectric domain walls in $BiFeO_3$

— •Sabine Körbel[1,2], Stefano Sanvito[1], and Jirka Hlinka[2] — [1]School of Physics & CRANN, Trinity College Dublin, Ireland — [2]Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic

Ferroelectric domain walls are objects capable of creating local electric fields in ferroelectric materials, and therefore in principle allow for a domain-wall driven photovoltaic effect. However, up to now the magnitude of such a domain-wall photovoltage was never measured nor calculated directly: experimentally it is hard to distinguish between domain-wall and bulk photovoltaic effect; first principles calculations used only an indirect approach based on the ionic polarization in the dark state, neglecting the electronic polarization. In order to directly calculate the domain-wall photovoltage in $BiFeO_3$, we modeled the excitonic charge density upon light irradation from first principles and determined the potential variations at the domain walls and consequently the domain-wall photovoltage. We find indeed that excitons form an electric dipole layer at the domain walls resulting in a domain-wall driven photovoltage, and that the excitonic dipole moment is aligned parallel to the net polarization, not, as previously assumed, antiparallel. By comparing the calculated domain-wall photovoltage to the total photovoltage measured in experiment, we conclude that the domain-wall effects are relatively small and cannot account for the major part of the measured photovoltage. This indicates that bulk effects, not domain-wall effects, dominate the photovoltage in $BiFeO_3$.

MA 42: Posters Magnetism I

Time: Wednesday 15:00–18:00 Location: P3

MA 42.1 Wed 15:00 P3

Nonlinear effects in nano-YIG

— •Martin Kewenig[1], Morteza Mohseni[1], Julius Balliet[1], Felix Kohl[1], Michael Schneider[1], Björn Heinz[1], Qi Wang[1], Bert Lägel[2], Carsten Dubs[3], Andrii Chumak[4], Philipp Pirro[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Nano Structuring Center, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [4]Faculty of Physics, University of Vienna, Vienna, Austria

Spin waves show many characteristics, which make them suitable for future information technology. For example, they feature intrinsic strong nonlinear behavior. Since nonlinear effects are important to build logic devices, it is of high interest to understand the underlying mechanism and to study nonlinear effects in nanoscaled devices. We show a nonlinear scattering effect from the fundamental mode to the first and second perpendicular standing spin-wave mode in a micro structured, 85 nm thick Yttrium-Iron-Garnet waveguide. The scattering process has been investigated by frequency- and time-resolved Brillouin-light-scattering spectroscopy. Field- and power-dependent measurements indicate a clear threshold behavior of the investigated phenomenon. This research has been supported by: EU Horizon 2020 research and innovation programme within the CHIRON project (contract number 801055), DFG SFB/TRR 173 Spin+X, Project B01, ERC Starting Grant 678309 MagnonCircuit and DFG (DU 1427/2-1).

MA 42.2 Wed 15:00 P3

Sub-micrometer near-field focusing of spin waves in ultra-thin YIG films — •Boris Divinskiy[1], Nicolas Thiery[2], Laurent Vila[2], Olivier Klein[2], Nathan Beaulieu[3], Jamal B. Youssef[3], Sergej O. Demokritov[1], and Vladislav E. Demidov[1] — [1]University of Münster, Münster, Germany — [2]Univ. Grenoble Alpes, CNRS, CEA, Grenoble INP, IRIG-SPINTEC, Grenoble, France — [3]LabSTICC, CNRS, Université de Bretagne Occidentale, Brest, France

We experimentally demonstrate tight focusing of a spin wave beam excited in extended nanometer-thick films of Yttrium Iron Garnet by a simple microscopic antenna functioning as a single-slit near-field lens. We show that the focal distance and the minimum transverse width of the beam can be controlled in a broad range by varying the frequency/wavelength of spin waves and the antenna geometry. The experimental data are in good agreement with the results of numerical simulations. Our findings provide a simple solution for implementation of magnonic nano-devices requiring local concentration of the spin-wave energy.

MA 42.3 Wed 15:00 P3

Bridging magnonics and spin-orbitronics — •Boris Divinskiy[1], Vladislav E. Demidov[1], Sergei Urazhdin[2], and Sergej O. Demokritov[1] — [1]University of Münster, Münster, Germany — [2]Emory University, Atlanta, USA

The emerging field of nano-magnonics utilizes high-frequency waves of magnetization - the spin waves - for the transmission and processing of information on the nanoscale. The advent of spin-transfer torque has spurred significant advances in nano-magnonics, by enabling highly efficient local spin-wave generation in magnonic nanodevices. Furthermore, the recent emergence of spin-orbitronics, which utilizes spin-orbit interaction as the source of spin torque, has provided a unique ability to exert spin torque over spatially extended areas of magnonic structures, enabling enhanced spin-wave transmission. Here, we experimentally demonstrate that these advances can be efficiently combined. We utilize the same spin-orbit torque mechanism for the generation of propagating spin waves, and for the long-range enhancement of their propagation, in a single integrated nano-magnonic device. The demonstrated system exhibits a controllable directional asymmetry of spin wave emission, which is highly beneficial for applications in non-reciprocal magnonic logic and neuromorphic computing.

References:

[1] B. Divinskiy et al., Adv. Mater. 1802837 (2018)

MA 42.4 Wed 15:00 P3

Implementation of the Stimulated-Raman-Adiabatic-Passage mechanism in magnonics — Qi Wang, •Anna M. Friedel, Thomas Brächer, Andrii V. Chumak, Burkard Hillebrands, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany

The Stimulated Raman Adiabatic Passage (STIRAP) is a process known from atomic physics which describes the population transfer between two states, where direct transitions are dipole forbidden, using a specific coupling scheme to a third state. The STIRAP process has found various applications in many fields of physics [1] and has already been implemented in the field of waveguide optics [2]. We present first results of the magnonic realisation of the STIRAP process. Our demonstrator consists of three, partially curved magnonic waveguides, which are locally coupled via the dipolar stray fields of magnons in well-defined regions of small separation between two neighbouring waveguides. Using micromagnetic simulations, we show that the population of magnons can be transferred between the outer waveguides via the intermediate waveguide. Analogous to the atomic STIRAP process, if the "counterintuitive" coupling scheme is used, the intermediate waveguide is not excited during the transfer. This implementation of a mechanism known from the field of quantum control and coherent control into magnonic functionalities is one of many quantum-classical analogy phenomena that could be transferred to magnonics.

[1] K. Bergmann et al., J. Phys. B 52, 202001 (2019)
[2] S. Longhi, Laser Photonics Rev. 3, 243 (2009)

MA 42.5 Wed 15:00 P3

Three-magnon scattering in a displaced magnetic vortex — •Lukas Körber[1,2], Katrin Schultheiss[1], Tobias Hula[1], Roman Verba[3], Attila Kákay[1], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Germany — [2]TU Dresden, Germany — [3]Institute of Magnetism, National Academy of Sciences of Ukraine, Kyiv, Ukraine

In a small ferromagnetic disk which is magnetized in the vortex state, only a discrete set of spin-wave modes exists due the confinement as well as the cylindrical symmetry. When a radial mode is excited above certain threshold power it may decay into two azimuthal spin-wave modes via a process called three-magnon scattering. The three-magnon scattering in such a case has been found to obey certain selection rules which lead for the mode profiles of the secondary waves to be distinct from each other [1]. Here, we study the stability of this process when the cylindrical symmetry is broken by displacing the vortex with an external magnetic field. We find that the selection rules are maintained and three-magnon scattering into two different azimuthal modes persists below the vortex annihilation field. Moreover, we observe the appearance of additional secondary modes which appear for a certain range of external fields and for lower excitation field powers than the regular vortex modes. Financial support of within DFG programme SCHU 2922/1-1 and KA 5069/1-1 is acknowledged.

[1] Phys. Rev. Lett. 122, 097202

MA 42.6 Wed 15:00 P3

Spinwave propagation and mode conversion in an asymmetric YIG fork structure — •Julius Balliet[1], Martin Kewenig[1], Frank Heussner[1], Felix Kohl[1], Bert Lägel[2], Carsten Dubs[3], Andrii Chumak[4], Philipp Pirro[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik und Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Nano Structuring Center, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [4]Faculty of Physics, University of Vienna, Vienna, Austria

Spin waves are collective excitations in the spin system of a magnetic material. They show many characteristics, which make them suitable as data carriers in data processing. A promising device is a spin wave based majority gate consisting of three inputs and one output in a forklike structure. As a foundation to implement such a nanoscale majority gate, the spin wave propagation in a Yttrium-Iron-Garnet fork microstructure was observed via frequency-resolved Brillouin-light-scattering spectroscopy in addition to micromagnetic simulations. Two-dimensional spin wave intensity distributions of the combining area of two inputs show that the spin waves propagate in beams not parallel to the connecting waveguide which ends in a zigzag intensity profile. This research has been supported by: EU Horizon 2020 research and innovation programme within the CHIRON project (contract number 801055), DFG SFB/TRR 173 Spin+X, Project B01, ERC Starting Grant 678309 MagnonCircuit and DFG (DU 1427/2-1).

MA 42.7 Wed 15:00 P3

First electrical detection of a magnon BEC in bulk-YIG — •Timo B. Noack, Vitaliy I. Vasyuchka, Burkard Hillebrands, and Alexander A. Serga — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Magnons are weakly ineracting bosonic quasi-particles and therefore they are able to form a Bose-Einstein condensate even at room temperatures. The comparable easy technique of generation of the BEC in magnonic systems, the possibility of its creation at ambient conditions and its potential for the application of this macroscopic quantum state in post-Von-Neumann computing make this research field to a large growing part of the modern magnonics. In this contribution we demonstrate the first measurements of magnon BECs in bulk-sample. A clear threshold of the applied pumping power for the condensation of magnons at the lowest energy state was found. The direct electrical measurement of this lowest state reveals the expected narrow frequency bandwidth and confirmes, thus, the population of a single quantum state. Coincidentally with the sudden narrowing at this treshold a drastic increase in the decay time of the signal can be observed. Financial support of the European Research Council within the Advanced Grant 694709 SuperMagnonics "Supercurrents of MagnonCondensates for Advanced Magnonics" is gratefully acknowledged.

MA 42.8 Wed 15:00 P3

Investigation of parallel parametric pumping processes in

individual YIG nanostructures — •Akira Lentfert[1], Björn Heinz[1,2], Morteza Mohseni[1], Michael Schneider[1], Burkard Hillebrands[1], Andrii V. Chumak[3], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Nanomagnetism and Magnonics, Faculty of Physics, University of Vienna, Vienna, Austria

Yttrium iron garnet (YIG) is a unique material with outstanding magnetic properties such as the lowest known spin-wave damping. It is therefore a promising candidate for the application in spin-wave based circuits and logic devices. Nevertheless, the ability to amplify the spin-wave amplitude and to increase the travel distance is crucial for the realization of such spin-wave logic networks. Parallel parametric pumping is a powerful tool in this regard, which allows for the generation and amplification of spin waves while conserving the phase. In this work, we investigate the parallel parametric generation in individual nanosized YIG conduits with lateral dimension down to 50 nm. Time resolved micro-focused Brillouin-Light-Scattering spectroscopy is used to measure the generated spin-wave spectrum directly below the pumping area, and the pumping threshold is extracted. This research has been supported by ERC starting Grant 678309 MagnonCircuits, DFG Grant DU 1427/2-1 and the Graduate School Material Science in Mainz (MAINZ).

MA 42.9 Wed 15:00 P3

Magnon condensation in the presence of magnetoelastic interaction — •Vitaliy I. Vasyuchka[1], Pascal Frey[1], Mio Ishibashi[2], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institute for Chemical Research, Kyoto University, Kyoto, Japan

We report on the investigation of the magnon condensation in the presence of the magnetoelastic interaction in different areas of the magnon phase space. Energy spectra of an overpopulated magnon-phonon gas were studied at room temperature in an yttrium iron garnet (YIG, $Y_3Fe_5O_{12}$) film by frequency-, time- and wavevector-resolved Brillouin light scattering (BLS) spectroscopy under different pumping and bias magnetic field conditions. The population of magnon-phonon spectra and its time evolution demonstrate a strong interaction between condensed magnons and accumulated magnetoelastic quasiparticles, when they are located close to each other in the phase space.

Financial support by the European Research Council (ERC) within the Advanced Grant "SuperMagnonics" (Grant agreement No. 694709) is gratefully acknowledged.

MA 42.10 Wed 15:00 P3

Spin-wave packets triggered by ultrashort laserpulses — •Tobias Tubandt[1], Justyna Rychly[2], Jakob Walowski[1], Christian Denker[1], Jaroslav Klos[2], and Markus Münzenberg[1] — [1]Institute of Physics, University Greifswald, Germany — [2]Faculty of Physics, Adam Mickiewicz University Poznań, Polen

The theoretical foundations to magnons and spin-waves has already been established in 1940 by Felix Bloch, yet magnonics itself remains a vivid research field. The advance in nanotechnology and the development of experimental techniques to analyse magnetization dynamics in the recent years bring a growing interest in the search for technologies, which utilize spin-waves to store, carry and process information. We investigate broadband excitations of spin-wave packets by ultrashort laser pulses in magnonic antidot crystals and one-dimensional stripe patterns varying the stripe broadness. The propagation distance in the antidot lattices depends on the direction of the applied magnetic field as well as the surface geometry of the crystal. Additionally, spatially resolved magnetization dynamics measurements on thin CoFeB films reveal that the frequencies of resulting spin-wave modes depend strongly on the distance to the pump center, due to the laser generated temperature profile, which leads to a 0.5 GHz shift in the spin-wave frequency and persists for up to one nanosecond. For the stripe patterns, micromagnetic simulations predict a distance dependent frequency shift. This behavior can be confirmed experimentally.

MA 42.11 Wed 15:00 P3

A novel approach for growing low-loss ferrimagnetic garnet nanofilms — •Christopher Heins, Robert Gruhl, Vasily Moshnyaga, and Henning Ulrichs — 1. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The ferrimagnetic insulator Yttrium iron garnet (YIG) is a popular material in magnonics due to its ultra-low magnetic damping. Thereby, it is well suited to study fundamental physics like magnon Bose-Einstein condensation, and realize filtering applications in microwave electronics. While liquid phase epitaxy methods allow since many decades to grow YIG films with micrometer thickness, nowadays pulsed laser deposited (PLD) YIG films with thicknesses of few nanometers are in the scientific focus. On this poster we report on such YIG nanofilms, which were grown by metal-organic aerosol deposition (MAD) as an alternative approach. This method allows to synthesize complex oxide films directly from its atomic constituents. Besides characterization of structural and magnetic properties by XRD and SQUID, we use a custom-built stripline Ferromagnetic Resonance setup to determine dynamic magnetic properties. We find a Gilbert damping of about $(6.7\pm0.9)\cdot10^{-4}$, which is comparable with typical PLD grown films. We acknowledge financial support by the DFG within the CRC 1073.

MA 42.12 Wed 15:00 P3

THz spin-wave generation in optically-driven acoustic resonators — •Dennis Meyer, Vitaly Bruchmann-Bamberg, Christopher Heins, Sina Ludewig, Vasily Moshnyaga, and Henning Ulrichs — I. Physical Institute, Georg-August University Göttingen, 37077 Göttingen, Germany

Ultrafast optically-driven coherent THz spin wave sources are of crucial importance for high frequency spintronic applications. However, a monochromatic coherent spin-wave generation for frequencies $f = 0.1 - 6$ THz is hard to achieve using optical methods, which produce rather incoherent or non-monochromatic spin-waves. Magnetoelastic coupling, usually viewed as an undesirable dissipation channel in spintronics, was recently shown to generate spin currents and coherent magnetic oscillations in the low GHz regime. Such experiments, utilizing microwave radiation, are practically restricted to frequencies less than 10 GHz. We propose a novel design to generate THz spin waves by laser excitation of an acoustic nanocavity. The idea is to apply a fs-laser pulse to generate a spectrally broad stress pulse in a metallic transducer layer (β-W or Pt) that passes a ferromagnetic layer (e.g. $La_{0.7}Sr_{0.3}MnO_3$ or CoFeB) featuring significant magneto-elastic coupling. Finally, it reaches a superlattice structure (e.g. $LaMnO_3/SrMnO_3$), which acts as a frequency selective Bragg mirror for phonons. By matching the dispersion of magnons and phonons, energy transfer from the phonon into a magnon mode occurs. We acknowledge financial support by the DFG within project A02 of the CRC 1073 *Atomic scale control of energy conversion*.

MA 42.13 Wed 15:00 P3

Spin Torques in Coupled YIG/Py Heterostructures — •Carolina Lüthi[1,2], Luis Flacke[1,2], Hans Huebl[1,2,3], Matthias Althammer[1,2], Rudolf Gross[1,2,3], and Mathias Weiler[1,2] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, Germany — [3]Nanosystems Initiative Munich, Germany

Modern spin-wave technology aims to encode and transport information using the electron spin-angular momentum. In this field, the ferrimagnetic insulator yttrium iron garnet (YIG) has numerous applications due to its low intrinsic Gilbert damping. We investigate spin dynamics due to interfacial spin torques in YIG/NiFe thin film heterostructures by broadband ferromagnetic resonance (FMR) spectroscopy. We observe an efficient excitation of perpendicular standing spin waves in the YIG layer, in agreement with our earlier findings [1]. Additionally, for oblique orientations of the external magnetic field and at cryogenic temperatures, we observe exchange-modes which hybridize with the FMR modes of Py and YIG. We study their dynamics as a model system for hybrid excitations in magnetic heterostructures.

Financial support by the DFG via project WE5386/5-1 is acknowledged.

[1] Stefan Klingler *et al.*, Phys. Rev. **120**: 127201 (2018)

MA 42.14 Wed 15:00 P3

Non-linear spin-wave generation at low magnetic bias fields — •Rouven Dreyer, Chris Körner, Niklas Liebing, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

For small magnetic stiffnesses the non-linear spin-wave excitations are not adequately described by Suhl instability processes [1]. It was shown that in this regime spin waves at fractional multiples of the pump frequency (such as 3/2 ω) are excited [1]. Here we demonstrate the 3/2 ω non-linear spin-wave (NLSW) generation in $Ni_{80}Fe_{20}$ microstructures using different scanning magneto-optical microscopy approaches. A special version time-resolved Kerr microscopy [2] allows for phase-resolved imaging and provides access to the wave vectors of parametrically excited NLSW at 3/2 ω above the threshold rf-field. The threshold behavior of this type of non-linearities is compared with results from a NV-center photoluminescence microscope using the same sample. Since the NV-center is very small signal averaging in the area of the laser spot is avoided, therefore a lack of phase stability in space and time does not reduce the signal and the NV-centers can be utilized to investigate the NLSW excitation for large wave vectors close to the threshold condition. Our results are further supported by micro-focussed Brillouin light scattering (μ-BLS) experiments performed on the same samples. [1] H. G. Bauer et al., Nat. Commun. 6:8274 (2015) [2] R. Dreyer et al., arXiv:1803.04943 (2018)

MA 42.15 Wed 15:00 P3

Sub-wavelength THz measurements of small crystals: chiral Ni_3TeO_6 — •David Maluski[1], Malte Langenbach[1], David Szaller[2], István Kézsmárki[3], Vladimir Tsurkan[3], Sang-Wook Cheong[4], Joachim Hemberger[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Festkörperphysik, Technische Universität Wien — [3]Experimentalphysik V, Universität Augsburg — [4]Department of Physics and Astronomy Rutgers, The State University of New Jersey

For single crystals with dimensions in the mm range, THz spectroscopy faces the problem of diffraction when the wavelength becomes comparable to the sample size. For instance, the transmitted intensity is significantly suppressed with increasing wavelength, hampering a quantitative analysis. We show, however, that the phase of the photons reaching the detector still can be analysed quantitatively, extending the accessible range for THz spectroscopy to lower frequencies. As an example, we study a single domain of chiral Ni_3TeO_6 with circularly polarized light in high magnetic field, establishing the existence of directional dichroism. This effect can be attributed to the chiral and polar structure and the large dynamic magneto-electric susceptibility.

MA 42.16 Wed 15:00 P3

Non-equilibrium spin dynamics and statics enforced by spin currents in ferrimagnetic nanofilms — •Sina Ludewig, Dennis Meyer, and Henning Ulrichs — 1. Physical Institute, Georg-August-University Göttingen, 37077 Göttingen, Germany

On this poster, we report about our investigations of highly non-linear spin dynamics in nanometer-thick Yttrium-Iron-Garnet (YIG) films, induced by means of spin currents, which are generated via the spin-Hall effect. Using micromagnetic simulation we identify a dynamic regime hosting localized, non-propagating solitons, a turbulent chaotic regime, as well as a quasi-static phase featuring a stripe-like magnetization texture, and eventually at largest spin current a homogeneously switched state. To actually realize such dynamics, we propose YIG films grown by metal-organic aerosol deposition, as well as sputtered beta-tungsten (β-W) as a material with large spin-Hall angle. Concerning β-W, we include on this poster our recent progress regarding the reproducible growth of this non-equilibrium structural phase.

We acknowledge financial support by the DFG within the SFB 1073.

MA 42.17 Wed 15:00 P3

Concept of Brillouin light scattering spectroscopy of magnons in optically-induced 2D magnetic landscapes — •Matthias R. Schweizer, Alexander J.E. Kreil, Vitaliy I. Vasyuchka, Georg von Freymann, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik und Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Brillouin light scattering spectroscopy (BLS) is an important tool for the investigation of spin waves (SW) and their quanta, magnons, in a wide frequency and wave vector ranges. It allows for the measurement of magnon density with high spatial and temporal resolutions.

On the other hand, it has been shown that optically induced magnetization landscapes are a powerful tool to control the propagation dynamics of externally excited spin waves. Furthermore, they can be used to propel a supercurrent spin transport in Bose-Einstein magnon condensates. Such landscapes can be created by using a spatial light modulator (SLM), which is able to project reconfigurable two-dimensional optical intensity patterns on a sample, heating it and thus forming periodic magnetization arrays and graded index structures.

We present a concept for the combination of both techniques, which results in a flexible method for the optical control and observation of two-dimensional magnon dynamics on mesoscopic and microscopic scales.

Support by SFB/TRR 173 Spin+X (project B04) is gratefully acknowledged.

MA 42.18 Wed 15:00 P3

Plasmonic Field Confinement for Ultrafast High-Harmonic Dichroic Microscopy — •Jakob Hagen, Sergey Zayko, Ofer Kfir, and Claus Ropers — 4th Physical Institute, University of Göttingen, Germany

The response of magnetic materials to abrupt laser excitation indicates evidences of intriguing femtosecond dynamics [1]. While a number of spectroscopic techniques were developed to get access and, potentially, unveil the physics behind this phenomenon, the direct observation of nanoscale spin dynamics in real space remains challenging [2] since it requires a nanometric resolution imaging, femtosecond temporal resolution and also nanoscopic excitation. In this study we develop such an excitation to trigger femtosecond spin dynamics, based on plasmonic nanostructures fabricated by electron beam lithography. These structures complement the nanometric imaging resolution using femtosecond pulses of high harmonic radiation [3]. This work would enable versatile sub-wavelength illumination profiles of the magnetic structure and may allow for magnon-selective excitation.

[1] E. Beaurepaire et al., *Phys. Rev. Lett.*, **76**, 22 (1996) [2] C. von Korff Schmising et al., *Phys. Rev. Lett.*, **112**, 217203 (2014) [3] O. Kfir et al., *Sci. Adv.*, **3** (12), eaao4641 (2017).

MA 42.19 Wed 15:00 P3

Study of Ultrafast Magnetization Dynamics in Perovskite Oxide Films by use of Extreme Ultraviolet Light — •Henrike Probst, Christina Möller, Johannes Otto, Cinja Seick, Matthijs Jansen, Sabine Steil, Daniel Steil, Vasily Moshnyaga, and Stefan Mathias — 1. Physikalisches Institut, Göttingen, Germany

Ultrafast spin dynamics has become an active field of research since the seminal work of Beaurepaire in 1996 [1]. Despite numerous experimental and theoretical works, the magnetization dynamics in complex systems such as alloys, multilayers and strongly correlated electron systems are still barely explored.

To investigate ultrafast magnetization dynamics in thin film perovskite oxides, we built up a new element-specific high-harmonic-generation-based magneto-optical Kerr (HHG-MOKE) setup. It allows to apply magnetic fields, B=0-1 T, and to vary the sample temperature, T=4-400 K, to control the magnetic phase of the film.

We will present first element-specific HHG-MOKE data on high quality thin perovskite films prepared by metalorganic aerosol deposition technique.

[1] E. Beaurepaire et al., Phys Rev Lett 76, 4250 (1996).

MA 42.20 Wed 15:00 P3

Finite size effects on the ultrafast remagnetization- and lattice dynamics of FePt — Alexander von Reppert[1], Lisa Willig[1], Jan-Etienne Pudell[1], Steffen Zeuschner[1,2], Gabriel Sellge[3,4], Fabian Ganss[3], Olav Hellwig[3,4], Jon Ander Arregi[5], Voitech Uhlíř[5], Aurelien Crut[6], and •Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam — [2]Helmholtz-Zentrum Berlin, Berlin — [3]Institut für Physik, TU Chemnitz, Chemnitz — [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [5]CEITEC BUT, Brno University of Technology, Brno, Czechia — [6]ILM, Université de Lyon, Villeurbanne, France

We investigate the coupling between the ultrafast lattice and magnetization dynamics of FePt in the $L1_0$ phase after an optical heating pulse, as used in heat assisted magnetic recording. We compare continuous and nano-granular thin films and emphasize the impact of the finite size on both the strain response and the remagnetization dynamics. Our timeresolved MOKE experiments show that the remagnetization dynamics for the single-domain FePt nanograins is dictated by the cooling, whereas it strongly depends on the field-dependent domain-wall motion for the continuous FePt-film. By combining ultrafast X-Ray diffraction and FEM-modeling we show that the concomitant lattice response in both specimen is governed by the varying degrees of in-plane motion for both specimen. We present a versatile two-pulse excitation scheme in which the first laser pulse induces a demagnetization, while the second pulse triggers a strongly magnetization-dependent lattice response in the FePt nanograins.

MA 42.21 Wed 15:00 P3

Ultrafast Photoinduced Spin Dynamics and Transmission Transients in the Strongly Correlated Manganite $Pr_{0.9}Ca_{0.1}MnO_3$. — •Tim Titze[1], Hendrik Meer[1], Birte Kressdorf[2], Andreas Weisser[1], Cinja Seick[1], Henning Ulrichs[1], Dennis Meyer[1], Christian Jooss[2], Daniel Steil[1], and Stefan Mathias[1] — [1]1st Physical Institute, University of Goettingen — [2]Institute for Materials Physics, University of Goettingen

We investigate spin and quasiparticle dynamics of a thin $Pr_{0.9}Ca_{0.1}MnO_3$ (PCMO) film, using time resolved transient transmission and magneto-optical Kerr measurements. A cryostat provides the opportunity to study the temperature-dependent properties of this strongly correlated manganite in a temperature range of 20 K - 300 K. At low temperatures (<100 K) we observe a ferromagnetic phase using TR-MOKE, which can be connected to features observed in transient transmission data. The data shows an initial ultrafast increase in magnetization on a sub-ps timescale, followed by a slower demagnetization within tens of ps. In further transient transmission measurements we observe an ultrafast transmission change within less than a picosecond and a slow 100 ps - 1 ns relaxation component, whose T-dependence hints at a proposed phase transition out of the low-temperature orbitally ordered phase around 200 K.

MA 42.22 Wed 15:00 P3

Time-resolved x-ray magnetic circular dichroism on Co/NiMn and Ni/NiMn bilayers — •Ivar Kumberg[1], Rahil Hosseinifar[1], Sakineh Ghaderi[1], Evangelos Golias[1], Sangeeta Thakur[1], Niko Pontius[2], Christian-Schuessler Langeheine[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin Albert-Einstein-Straße 15, 12489 Berlin, Germany

In order to achieve a better understanding of ultrafast demagnetization processes in coupled systems including transport and exchange coupling effects, we studied stacks of adjacent ferromagnetic and antiferromagnetic layers by time-resolved pump-probe x-ray magnetic circular dichroism. Measurements were done using 60 fs laser pump and 100 fs X-ray probe pulses provided by the FemtoSpeX facility at BESSY II. 15 monolayers (ML) Co/24 ML $Ni_{30}Mn_{70}$ and 15 ML Ni/15 ML $Ni_{30}Mn_{70}$ bilayers were grown by molecular beam epitaxy on Cu(001) and growth was monitored by medium-energy electron diffraction and Auger electron spectroscopy.

We interpret our data by using the two- and three-temperature model as well as a phenomenological description following the solution of these models. The aim is to extract the demagnetization times in dependence of temperature, laser fluence, and layer thickness. The demagnetization times are in the range of 100 to 170 fs and follow the expected temperature dependence.

MA 42.23 Wed 15:00 P3

Investigation of ultrafast laser-induced toggle-switching and domain-wall motion in GdFe — •Rahil Hosseinifar[1], Ivar Kumberg[1], Evangelos Golias[1], Sangeeta Thakur[1], Florian Kronast[2], Manfred Albrecht[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Using purely optical means to manipulate the magnetization direction is an interesting way to introduce new potential applications in spintronic devices. Excitation of certain materials by femtosecond laser pulses causes magnetization reversal, irrespective of the magnetization direction. Subsequent pulses thus reverse the magnetization back and forth, which is called "toggle switching". We study 15 nm thin films of ferrimagnetic GdFe alloys with in-plane and out-of-plane easy axes by X-ray magnetic circular dichroism photoelectron emission microscopy (XMCD-PEEM) using the laser at the SPEEM facility at UE49-PGM1 of BESSY II in Berlin. XMCD-PEEM images after individual linearly polarized laser pulses show clear laser-induced magnetization changes. We observe deterministic and local nondeterministic toggle switching for out-of-plane $Gd_{26}Fe_{74}$ films over a considerable range of laser fluences. The in-plane-magnetized $Gd_{21}Fe_{79}$ sample shows lateral displacements of domain walls of up to several μm after laser excitation.

MA 42.24 Wed 15:00 P3

The role of coherent and incoherent phonons for the excitation of standing spin waves — •Steffen Peer Zeuschner[1,2], Marwan Deb[1], Alexander von Reppert[1], Jan-Etienne Pudell[1], Elena Popova[3], Niels Keller[3], Matthias Rössle[2], Marc Herzog[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Wilhelm-Conrad-Röntgen Campus, BESSY II, 12489 Berlin, Germany — [3]Groupe d'Etude de la Matiére Condensée (GEMaC), CNRS UMR 8635, Université Paris-Saclay, 78035 Versailles, France

We present ultrafast X-ray diffraction (UXRD) and magneto-optical Kerr-effect (MOKE) measurements of the ferrimagnetic insulator bismuth-doped yttrium iron garnet (Bi:YIG). We compare the response of direct optical excitation of a Bi:YIG thin film with femtosecond laser pulses to the indirect excitation mediated by a thin metal transducer. In both cases, a coherent phonon wavepacket instantly traverses the Bi:YIG layer as a result of ultrafast deposition of energy. The main difference are incoherent phonons which are stimulated immediately inside the directly excited Bi:YIG layer but diffuse into the Bi:YIG layer on the timescale of hundreds of picoseconds after exciting the metal transducer. We analyze the response of the magnetic system to the coherent and incoherent phonons in the form of ultrafast demagnetization and standing spin waves (SSW). Via the quantitative assessment of the strain we disentangle the combination of heat and sound in the context of ultrafast stimulation of SSWs.

MA 42.25 Wed 15:00 P3

Electron scattering dynamics with anisotropic excitation — •Marius Weber, Kai Leckron, and Hans Christian Schneider — University of Kaiserslautern, Kaiserslautern, Germany

Ultrafast electron scattering plays an important role in different systems with itinerant carriers such as optically excited ferromagnets or transition metal dichalcogenides. While momentum-dependent electron scattering has been studied extensively in optically excited semiconductors [1,2], these studies were confined to isotropic parabolic model band structures. Here, we calculate electronic dynamics at the level of Boltzmann scattering integrals with and without non-Markovian effects, which lead to a broadening of the energy conservation condition following the approach of Ref. [1]. We study how broadening effects influence the dynamics, in particular the behavior of the kinetic energy. In order to treat electronic dynamics in metallic systems, we have developed a numerical solution for the dynamical distribution function depending on the *momentum vector* that is applicable to more realistic band structures. Our approach leads to well-converged dynamics and is capable of treating up to 30^3 k-points in the three-dimensional Brillouin zone. In a first step we investigated the behavior of anisotropic excitation conditions in a single band.

[1] Bonitz et al., Journal of Physics: Condensed Matter. 8(33):6057 (1999)

[2] Haug and Jauho, Quantum Kinetics in Transport and Optics of Semiconductors, Springer, Berlin Heidelberg (2008)

MA 42.26 Wed 15:00 P3

Numerical solution of linearized electron-electron scattering integrals for ultrafast dynamics and transport — •Félix Dusabirane, Kai Leckron, and Hans Christian Schneider — TU Kaiserslautern, Kaiserslautern, Germany

We study electronic dynamics due to electron-electron scattering in the framework of a linearized Boltzmann collision integral for bandstructures with 3-dimensional Brillouin zones. We present a numerical scheme that allows one to obtain excellent conservation of the carrier density over several tens of picoseconds with a limited numerical effort. We benchmark this scheme for parabolic carrier dispersions against quasi 1-dimensional calculations and analytical results [1]. We also discuss how this approach can be extended to calculate electronic scattering contributions for models of hot-electron transport [2].

[1] V. V. Kabanov and A. S. Alexandrov, Phys. Rev. B 78, 174514 (2008).

[2] D. M. Nenno, B. Rethfeld, and H. C. Schneider, Phys. Rev. B 98, 224416 (2018).

MA 42.27 Wed 15:00 P3

Ultrafast magnetization dynamics in TbGd bilayers and the effect of interlayer angular momentum transport — •Markus Gleich[1], Kamil Bobowski[1], Dominic Lawrenz[1], Can Çağincan[1], Niko Pontius[2], Daniel Schick[2], Torsten Kachel[2], Christian

Schüssler-Langeheine[2], Björn Frietsch[1], Unai Atxitia[1], Nele Thielemann-Kühn[1], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin

We studied the ultrafast magnetization dynamics in TbGd bilayers by XMCD in reflection at the FemtoSpeX facility of BESSY II. The bilayers were epitaxially grown on W(110) and show a two-step demagnetization as observed for Gd and Tb [1-3]. Already few layers of Tb influence the temperature-dependent magnetization of the Gd layer. This interaction depends on the distance to the interface suggesting substantial Gd-Tb spin-coupling. We obtained good agreement between experimental results on ultrafast magnetization dynamics and simulations based on the M3TM [4], which has been extended to account for temperature-dependent thermal conductivity and heat capacity, and most importantly interlayer spin transport.

[1] M. Wietstruk *et al.*, Phys. Rev. Lett. **106**, 127401 (2011).
[2] A. Eschenlohr *et al.*, Phys. Rev. B **89**, 214423 (2014).
[3] K. Bobowski *et al.*, J. Phys.: Condens. Matter **29**, 234003 (2017).
[4] B. Koopmans *et al.*, Nat. Mater. **9**, 259–265 (2010).

MA 42.28 Wed 15:00 P3

Time resolved magnetostriction in itinerant ferromagnet $SrRuO_3$ — Maximilian Mattern[1], •Jan-Etienne Pudell[1], Alexander von Reppert[1], Marc Herzog[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany

We present ultrafast x-ray diffraction (UXRD) measurements of the ferromagnet $SrRuO_3$ using 200 femtosecond x-ray pulses derived from a laser based plasma x-ray source. Optical excitation of a 20 nm $SrRuO_3$ layer by femtosecond laser pulses instantaneously heats up the electron gas. In the paramagnetic phase the deposited energy couples to the phonons and leads to a lattice expansion. In the ferromagnetic phase a part of the deposited energy is transferred to the spin degrees of freedom. This results in a reduced lattice expansion in the ferromagnetic phase due to a pronounced magnetostriction. In the ferromagnetic phase of $SrRuO_3$ the energy transferred from the electrons to the spin system leads to a lattice contraction, whereas heating the phonon system leads to expansion. We model the generated lattice dynamics after laser excitation and analyze the saturation of the spin excitation upon systematic variation of the starting temperature and excitation fluence.

MA 42.29 Wed 15:00 P3

Magnetization dynamics in yttrium-iron-garnet/spin-cross-over bilayer systems — •Rostyslav Serha[1], Michael Schneider[1], Tim Hochdörfer[1], Juliusz Wolny[1], Björn Heinz[1], Carsten Dubs[2], Volker Schünemann[1], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany. — [2]INNOVENT e.V. Technologieentwicklung, D-07745 Jena, Germany

Spin-Cross-Over (SCO) materials are a promising approach to introduce an additional degree of freedom to the field of magnonics. The temperature induced, hysteretic switching of such materials between their diamagnetic and paramagnetic state potentially allows for a temperature-controlled manipulation of the magnetization dynamics in future magnonic devices. Here we investigate the influence of a SCO-layer coated on top of a thin film of yttrium-iron-garnet (YIG) on the magnetic parameters of the bilayer system. Using Vector-Network-Analyzer Ferromagnetic Resonance (FMR) spectroscopy the magnetic parameters, such as the effective saturation magnetization, the Gilbert damping and the linewidth of the FMR are derived at different temperatures. The phase transition of the SCO-material is found to be accompanied by an increased linewidth. The results obtained provide new insight into the behaviour of spin waves in YIG/SCO-systems and open up new avenues in the development of new magnonic logic gates. This research has been supported by: DFG SFB/TRR 173 Spin+X, Project B01, A04.

MA 42.30 Wed 15:00 P3

Relaxation of classical spins coupled to a conduction-electron system with dissipative boundaries — •Michael Elbracht and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

The real-time dynamics of a few classical impurity spins locally exchange-coupled to a conduction-electron system is investigated numerically. Starting from a locally excited initial state with a non-collinear impurity-spin configuration, we study the energy and spin dissipation as well as the final relaxation to the ground state. To circumvent finite size effects, a dissipative Lindblad bath is coupled to the system edges which absorbs the outgoing spin excitations. This allows a study of unperturbed real-time dynamics on essentially arbitrary long time scales.

The long-time relaxation of the classical impurity spins is traced as a function of various parameters, such as the exchange interaction or the number and the position of the spins. While the system in fact relaxes completely for an even number of impurity spins, an incomplete relaxation is observed for an odd number, i.e., the system stays in a metastable state. This unconventional behavior is attributed to additional symmetries that dynamically emerge and constrain the time evolution for states with an average energy already close to the ground state energy. The odd-even effect is understood by linearizing the equations of motion close to the manifold of classically degenerate ground states.

MA 42.31 Wed 15:00 P3

Broadband Ferromagnetic Resonance on sputtered YIG and Permalloy thin films — •Luise Siegl, Richard Schlitz, and Sebastian T. B. Goennenwein — Institut für Festkörper- und Materialphysik, Technische Universität Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden, Germany

Broadband ferromagnetic resonance (bbFMR) is a powerful tool to characterize the magnetic properties of magnetic materials. We have assembled a setup and a data evaluation protocol for broadband ferromagnetic resonance measurements for frequencies up to 50GHz. To characterize the setup performance, we measure the magnetic resonance response and the (Gilbert) magnetization damping of thin $Y_3Fe_5O_{12}$ (YIG) and $Ni_{80}Fe_{20}$ (Permalloy) films. We will systematically discuss the corresponding data, and furthermore address our strategy to extract the bbFMR signal from the 'non-magnetic' background. To this end, we take advantage of a background substraction approach put forward recently [1]. Using this approach we find a Gilbert damping of $\alpha = 4.16 \cdot 10^{-4}$ in $Y_3Fe_5O_{12}$ thin films.

We acknowledge funding by the Deutsche Forschungsgemeinschaft (DFG) via SFB1143/C08.

[1] Hannes Maier-Flaig *et al.*, Review of Scientific Instruments **89**, 076101 (2018)

MA 42.32 Wed 15:00 P3

Analysis of Terahertz Emission Profiles from Optically-Excited Magnetic Multilayers — •Dennis Nenno[1,2,3], Rolf Binder[2], and Hans Christian Schneider[1] — [1]TU Kaiserslautern — [2]University of Arizona — [3]Max Planck Institut für Chemische Physik fester Stoffe

Optically excited spin-currents lead to efficient terahertz emission from heavy metals via the inverse Spin-Hall effect [1]. We have developed an approach to simulate the dynamics of hot carriers in metallic multilayers by using a particle-in-cell approach to solve the Boltzmann transport equation. Using this framework, we study the effects of spin-dependent hot-carrier dynamics, as well as terahertz emission from Fe/Pt samples [2]. Our model reliably reproduces experimental findings and we show how the simulation clarifies the importance of the growth conditions [3]. From a genereal transfer-matrix analysis we demonstrate how simple, widely-used relations such as $E \propto \partial j/\partial t$ and $E \propto j$ between the field E and the dynamical charge current j in the emitter arise in the limiting cases of thin and thick layers.

[1] Seifert *et al.*, Nat. Photon. **10**, 483 (2016).
[2] Nenno, Binder & Schneider, Phys. Rev. Appl. **11**, 054083 (2019).
[3] Nenno *et al.*, Sci. Rep. **9**, 13348 (2019).

MA 42.33 Wed 15:00 P3

Engineering the interface of Iron/Platinum spintronic terahertz emitters — •Moritz Ruhwedel[1], Laura Scheuer[1], Rene Beigang[1], Evangelos Th. Papaioannou[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik, TU Kaiserslautern und Landesforschungszentrum OPTIMAS, Kaiserslautern, Germany — [2]Fachbereich Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Spintronic Fe/Pt-bilayer systems are considered as a accessible and low-cost approach for the generation of THz radiation. However, the influence of various properties of these bilayer systems is still subject of current research [1-3]. Here, we report on the influence of varied interface conditions for the high energy spin polarized electrons on the emitted THz radiation of the Fe/Pt-bilayer systems. Hereby, a variation of the interface between the Fe- and the Pt-layer is achieved by a variation of the fabrication temperature of the Pt-layer. The resulting transparency of the interface in the low energy regime with respect to the fabrication temperatures is characterized by means of Vector-Network-Analyzer Ferromagnetic Resonance (VNA-FMR) spectroscopy. An increased amplitude of the emitted THz radiation for larger values of the spin mixing conductivity in the low energy regime is observed, which potentially allows for an alternative characterization and further optimization of the spintronic THz-emitters.

[1] G. Torosyan et al., Sci. Rep. 8, 1311 (2018)
[2] E. Papaioannou et al., IEEE Trans. Magn 99, 1-5 (2018)
[3] D. Nenno et al., Sci. Rep. 9, 13348 (2019)

MA 42.34 Wed 15:00 P3

Super-resolution in THz-spectral imaging — •Tristan Winkel[1], Finn-Frederik Lietzow[1], Yuta Sasaki[2], Nina Meyer[1], Jana Kredl[1], Tobias Tubandt[1], Christian Denker[1], Jakob Walowski[1], Shigemi Mizukami[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Greifswald, Germany — [2]Advanced Institute for Materials Research, Tohoku University, Sendai, Japan

THz spectroscopy is attractive for scientific research, especially life science [1]. Its wavelength of several hundred μm usually limits its spatial resolution by diffraction. Super-resolution imaging techniques would be required to overcome this limit, while near-field imaging is probably the most feasible.

We investigate THz pulses by excitation of CoFeB/Pt layer stacks [2] and commercial Auston switch emitters with fs laser pulses. 2D motor-stages and LT-GaAs Auston switch detectors combined with Fourier transformation allow for spatially resolved THz spectroscopy.

The spatial resolution using the commercial emitter with focusing optics is half the wavelength. A drastic increase in spatial resolution appears using near-field imaging. A gold test pattern on the spintronic emitter leads to a spatial resolution of less than a tenth of the wavelength. The observation of FWHM of about 10 μm at 1 THz while having FHWM of 3 μm for the corresponding laser excitation using the "knife-edge method" demonstrates the high potential of our approach.

[1] S. K. Mathanker et al., ASABE 56 (2013).
[2] T. Seifert, Nature Photon, 10, pp. 483−488 (2016).

MA 42.35 Wed 15:00 P3

Inverse spin Hall Effect in ferromagnet/heavy metal bilayers with different spin orbit coupling materials and interlayers — •Mohamed Amine Wahada[1], Wolfgang Hoppe[2], Georg Woltersdorf[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale), Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06120 Halle, Germany

Spin pumping combined with the inverse spin Hall Effect (ISHE) is an essential tool in the field of Spintronics that can probe the dynamics of the magnetization of a ferromagnet when this latter is attached to a heavy metal or a spin orbit coupling (SOC) material. By using amplified femtosecond laser pulses, we generate ultrafast spin current pulses into heavy metal layers which are converted, via the ISHE, into ultrafast charge current pulses [1]. An rf probe tip is used to pick up these pulses and detect them in a fast sampling oscilloscope. Although the resultant waveform only has a bandwidth of about 30 GHz quantitatively (compared to the THz bandwidth of the electo-optical sampling method), this quick method provides a qualitative measure of the ISHE. Here, we investigate the influence of an MgO interlayer on the transmission of the spin current depending on the thickness of the oxide. The influence of other metal and oxide interlayers is investigated in terms of the modification of the interface transparency for the spin current pulses. In addition, different SOC materials ranging from heavy metals, topological insulators to Weyl semi-metals are compared. [1] T. Seifert et al. Nature Photon 10, 483-488 (2016)

MA 42.36 Wed 15:00 P3

Spin- and charge transport at THz frequencies in metallic multilayers: A 2-dimensional model — •Marcel Burgard, Dennis M. Nenno, and Hans Christian Schneider — Physics Department, TU Kaiserslautern, Kaiserslautern, Germany

We theoretically investigate spin and charge currents in metallic films and magnetic multilayers. These currents are driven by THz-fields via the inverse spin-Hall effect (ISHE) [1,2]. Frequencies in the THz regime have been shown to drastically alter the transport properties for electrons close to the Fermi energy [3], as they are described by wave-diffusion equations [3,4]. In order to study the impact of screening and ISHE on transport at THz frequencies we extend our model for an effectively one-dimensional calculation [3] to two dimensions and investigate the interaction between currents in different spatial directions.

[1] T. Kampfrath et al., Nature Nanotech 8, 256 (2013).
[2] T. Seifert, et al., Nature Photon 10, 483 (2016).
[3] L. Nadvornik et al., in preparation (2020).
[4] Y.-H. Zhu et al., Phys. Rev. B 78, 054429 (2008).

MA 42.37 Wed 15:00 P3

Piezoelectric Strain Control of Spin-Orbit Torques in CoFeB Thin Films — •M. Filianina[1], J.-P. Hanke[1,3], K. Lee[1], D.-S. Han[1], S. Jaiswal[1,4], G. Jakob[1], A. Rajan[1], Y. Mokrousov[1,3], and M. Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]Graduate School of Excellence Material Science in Mainz, Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich — [4]Singulus Technology AG, Kahl am Mainz, Germany

Energy-efficient control of magnetization in nanoscale is fundamental for designing future generation spintronic devices. In recent years current-induced magnetization switching via spin-orbit torques (SOTs), realized in ferromagnet/heavy metal bilayers, has emerged as one of the most promising approaches. The magnitude and the sign of the SOTs can be engineered by adjusting the system parameters. However, the SOTs are set once the device is fabricated, while in the light of potential applications the dynamical control of the SOTs is desired.

Here we demonstrate dynamic control of SOTs in perpendicularly magnetized W/CoFeB/MgO multilayers by electric field-induced strain. We find that modulated by an electric field tensile strain leads to a significant increase of the damping-like (DL) torque, while the compressive strain leads to its decrease. The field-like (FL) torque remains largely unaffected by strain. We compare our experimental results with theoretical ab initio calculations which explain the difference in the response of the FL and DL torques to the strain.

MA 42.38 Wed 15:00 P3

Ab initio calculations on Spin Hall Effect for metallic systems — •Alexander Fabian[1,2], Michael Czerner[1,2], Martin Gradhand[3], and Christian Heiliger[1,2] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen — [2]Zentrum für Materialforschung (LaMa), Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen — [3]H.H. Wills Laboratory, University of Bristol, UK

The Spin Hall Effect is a promising effect for use in spintronic devices since it provides a source for spin polarized currents. In order to achieve an efficient conversion of charge current to spin current, different materials have to be investigated. In order to tailor the material properties for efficient usage the properties have to be predicted with a reliable theoretical method. Normally, only the Spin Hall angles and spin conductivities are calculated by theory. On the other hand, optical experiments detect the spin accumulation spatially resolved. In our approach we use a Korringa Kohn Rostoker (KKR) Green's function method with the Keldysh non-equilibrium formalism to calculate a non-equilibrium density under applied bias. From this density we extract the spin accumulation throughout slabs of metal with strong spin orbit coupling for three different systems: Pt, Cu, U. The results of our approach are compared to the results of another KKR approach using the Boltzmann formalism. The origin of the effect should be only of intrinsic nature since there is no contribution of scattering.

MA 42.39 Wed 15:00 P3

Spin Hall Magnetoresistance in normal metal/yttrium iron garnet heterostructures — •E. Karadza[1,2], T. Wimmer[1,2], J. Gueckelhorn[1,2], R. Gross[1,2,3], H. Huebl[1,2,3], and M. Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

In the field of spintronics, the generation and detection of pure spin currents, i.e. the flow of angular momentum without an accompanying charge current, is an important building block for future spin logic applications. For the generation and detection of pure spin currents the (inverse) spin Hall effect (SHE) in metals with spin-orbit coupling is conveniently utilized. The SHE allows to convert a charge current into a pure spin current. The efficiency of this process is characterized by the spin Hall angle (SHA). Over the last decade many different materials have been investigated to increase the SHA. Here, we present our recent results on determining the SHA via spin Hall magnetoresistance measurements in normal metal (Pt, PtAu)/yttrium iron garnet heterostructures. Our systematic investigation as a function of the normal metal thickness allows us to identify promising materials for efficient pure spin current injection into magnetically ordered insulators. Financial support by the DFG is gratefully acknowledged.

MA 42.40 Wed 15:00 P3

Current induced switching of the Néel vector in CoO(001)/Pt bilayers — •Christin Schmitt[1], Lorenzo Baldrati[1], Romain Lebrun[1], Andrew Ross[1,2], Rafael Ramos[3], Eiji Saitoh[3,4], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]WPI-AIMR, Tohoku University, Sendai, Japan — [4]Department of Applied Physics, The University of Tokyo, Japan

Spintronics using antiferromagnets is promising based on intrinsic dynamics in the THz range and absence of stray fields. However efficient electrical writing and reading is necessary. This was shown in the insulating antiferromagnet NiO/heavy metal Pt thin film system (see for instance [1] and references therein), however a signal stemming from non-magnetic switching was also identified [2]. Here, we probe current-induced switching of the Néel vector in Hall crosses patterned on CoO(001)/Pt bilayers. We detect the Néel order by Spin Hall magnetoresistance (SMR) in a Hall-like geometry and switching is induced by current pulses via spin orbit torques. By looking at the switching above and below the Neél temperature in the CoO/Pt bilayer we can separate the "step-like" magnetic [1] and "triangular-like" non-magnetic switching signals [1,2], as the signal related to the antiferromagnetism disappears above Néel temperature. The non-magnetic signal, possibly related to a local annealing process and electromigration in the Pt layer, does not disappear. [1] L. Baldrati et al., PRL 123, 177201 (2019). [2] T. Matalla-Wagner et al., arxiv:1910.8576.

MA 42.41 Wed 15:00 P3

Spin transport in topological Floquet magnon insulator — •Jun-Hui Zheng[1], Roberto Troncoso[1], Walter Hofstetter[2], and Arne Brataas[1] — [1]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [2]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

In topological insulators, the edge states dominate transport at low temperature. In contrast, topological magnon insulators usually have relatively high-energy edge states. The spin transport is mainly arising from the bulk magnon states. Topological protected edge states are perfect channels for transport due to their robustness against disorder. Enhancing their occupation benefits the efficiency of transport. One method is to excite edges states by photons, a proposed amplification mechanism. Another possibility is to lower the energy of the edge states. Here we show that, by moderately driving the system, we can realize topologically protected edge states with zero energy, and amplify the contribution of spin transport from edge states.

MA 42.42 Wed 15:00 P3

Investigation of phonon interference for acoustically driven spin waves — •Felix Kohl[1], Moritz Geilen[1], Tobias Böttcher[1], Alexandra Nicoloiu[2], Florin Ciubotaru[3], Christoph Adelmann[3], Alexandru Müller[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]IMT, Bucharest, Romania — [3]IMEC, Leuven, Belgium

We present the investigation of two interfering phonon modes using Brillouin light scattering spectroscopy. For the spin wave excitation by surface acoustic waves it is of great importance to have a valid understanding of the exciting acoustic waves. For this work the surface acoustic waves are generated by interdigital transducers at GHz frequencies, which are commonly used in telecommunication technology. An investigation using BLS microscopy allows for measurements with a high spatial resolution at GHz frequencies. We could observe a characteristic interference pattern of phonon intensity behind the IDT. Wave-vector resolved BLS-measurements allow an explanation of the observed pattern with the interference of the Rayleigh mode and the first Sezawa mode. We acknowledge the support of the EU under H2020 FET Open Project CHIRON (grant agreement no 692519 2018 - 2021).

MA 42.43 Wed 15:00 P3

Growth of RuO_2 thin films and determination of magnetic and transport properties — •Sven Becker[1], Andrew Ross[1,2], Romain Lebrun[1], Lorenzo Baldrati[1], Mathias Kläui[1,2,3], and Gerhard Jakob[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

Recent theoretical studies predict a novel magnetoresistance effect, present in some collinear antiferromagnets with low crystal symmetry. The so called crystal Hall Effect [1] could permit one to detect electrically not only the direction of the antiferromagnetic Néel order but also its orientation. One candidate for the observation of this phenomena is the metallic antiferromagnet RuO_2. To be able to experimentally measure this predicted effect, one needs to fabricate high quality single crystalline samples with large antiferromagnetic domains. Here we show the growth of high quality thin films of RuO_2 on TiO_2 substrates by pulsed laser deposition. To determine transport properties continuous films have been patterned into Hall bars by e-beam lithography and argon ion etching. Unusual transport properties have been observed in RuO_2/TiO_2 as well as Pt/TiO_2 samples leading us to the conclusion that reductive conditions during the etching process leads to the modification of the TiO_2 substrate surface. [1] L. Šmejkal et al., arXiv:1901.00445 (2019)

MA 42.44 Wed 15:00 P3

Crystallisation of optically thick films of CoxFe(80-x)B20: evolution of the (magneto-) optical and structural properties — •Apoorva Sharma[1], Maria A. Hoffmann[2], Patrick Matthes[3], Olav Hellwig[1,4], Cornelia Kowol[2], Stefan E. Schulz[2,3], Dietrich R. T. Zahn[1], and Georgeta Salvan[1] — [1]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Center for Microtechnologies, Chemnitz University of Technology, 09126 Chemnitz, Germany — [3]Fraunhofer Institute for Electronic Nanosystems, 09126 Chemnitz, Germany — [4]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Co-Fe-B alloys are highly relevant materials for spintronic applications. In this work, the crystallisation of Co-Fe-B alloys triggered by thermal annealing was investigated by X-ray diffraction techniques and SEM, as well as spectroscopic ellipsometry and magneto-optical Kerr effect spectroscopy for annealing temperatures ranging from 300°C to 600°C. The transformation of ~100 nm thick CoxFe(80-x)B20 films from amorphous to polycrystalline was revealed by the sharpening of spectral features observed in the optical and magneto-optical dielectric functions spectra. The influence of B on the dielectric function was assessed both experimentally and by optical modelling. By analysing the Drude component of the dielectric function, a consistent trend between the charge carrier scattering time/resistivity and the annealing temperature was observed, in agreement with the electrical investigations by means of the four-point-probe method.

MA 42.45 Wed 15:00 P3

Current direction dependent frequency ranges of spin Hall nano-oscillators by adding a magnetic layer — •Toni Hache[1,2], Tillmann Weinhold[1], Yancheng Li[1], Jürgen Fassbender[1,3], Olav Hellwig[1,2], and Helmut Schultheiss[1,3] — [1]HZDR — [2]TU Chemnitz — [3]TU Dresden

Spin Hall nano-oscillators (SHNO) convert dc currents in microwave oscillations of the magnetization. The frequency can be tuned by external magnetic fields, the applied dc current or by injection locking if an additional microwave field is applied to the SHNO. Here, we demonstrate a new approach to extend the frequency range of a SHNO by adding an additional ferromagnetic layer. Moreover, the auto-oscillations can be switched from one to the other ferromagnetic layer by switching the current direction. A constriction-based SHNO consisting of a Py(5nm)/Pt(7nm)/CoFeB(5nm) layer stack with 2 nm Ta as seed and capping layer was used. If a dc current is applied to the structure, a pure spin current is generated by the spin Hall effect in the Pt layer. For a fixed current direction the spin polarization of the pure spin currents entering in the Py and CoFeB layers have opposite directions. Therefore, only one of both ferromagnetic layers experiences a decrease of damping due to the spin transfer torque and can show auto-oscillations of the magnetization. To change the frequency of the SHNO, the dc current direction has to be switched in order to switch the auto-oscillations to the other material with a different frequency range. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

MA 42.46 Wed 15:00 P3

Well Balanced Magnetic Gates for Inverted Logic — •Timo Pulch, Daniele Pinna, and Karin Everschor-Sitte — Johannes-Gutenberg Universität

We present an energy efficient solution for inverted logic gates by considering the self-interactions of magnets. Conventional magnetic logic gates have already been showing great results towards scaling and energy efficiency. In this work we present a series of reliable gate designs that are robust against finite temperature effects. The dipolar coupled monodomain magnet designs have been selected according to the fundamental metrics of balance and logical consistency. We argue that energy harvesting of the thermal fluctuations within this model can be used to stabilize the system in the desired logical states. In addition, we go one step further and show that carefully tuned gate structures are able to invert the logical processes of these gates. Invertible logic is a promising approach to solve NP problems.

MA 42.47 Wed 15:00 P3

Designing balanced magnetic logic gates by means of neural networks — •Lukas Holzbeck, Daniele Pinna, and Karin Everschor-Sitte — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Replacing traditional charged-based logic by nanomagnetic logic promises in particular the advantage of non-volatility. However to not lead to erroneous results upon integration to circuits, balanced logic gates are required. So far the search for such logic gates was rather on a trial and error base [cite https://journals.aps.org/prapplied/pdf/10.1103/PhysRevApplied.9.034004]. While such a search is consistently possible with only a few nanomagnets, it becomes rather infeasible for arrangements involving more nanomagnets. Our goal is to employ machine learning to design magnetic logic gates according to developed metrics of well-balanced and logical consistency. We train a neural network on data from static self-interacting systems and aim at finding generalized rules how to construct larger balanced gates and more complex logic gate structures such as the half adder.

MA 42.48 Wed 15:00 P3

Lattice effects accompanying the colossal magnetoresistance effect in $HgCr_2Se_4$ — •Steffi Hartmann[1], Shuai Yang[2], Yongqing Li[2], Jens Müller[1], and Michael Lang[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (Main), Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing, China

Understanding the origin of large or colossal magnetoresistance (CMR) effects, observed in a wide range of materials, remains a challenging field of research in magnetism. The universal occurrence of electronic and magnetic phase separation in some of these materials has led researchers to suggest a model of percolating magnetic polarons as a possible mechanism to explain the CMR effect. In fact, studies on the semi-metallic CMR material EuB_6 revealed that the magnetically-driven delocalization of charge carriers is accompanied by pronounced lattice distortions [1], consistent with the scenario of percolating nanoscale magnetic clusters. With reference to these results we performed high-resolution thermal expansion and magnetostriction measurements on the half-metallic CMR material $HgCr_2Se_4$, where the paramagnetic to ferromagnetic transition at 105 K drives an insulator-to-metal transition with an 8-orders-of-magnitude decrease of the longitudinal resistivity and a pronounced CMR effect [2]. We will discuss our results with respect to the coupling of the charge and magnetic degrees of freedom to the lattice distortion and compare our results with observations made for other CMR materials. [1] Manna et al., PRL 2014; [2] Guan et al., PRL 2015

MA 42.49 Wed 15:00 P3

Synthesis and crystal growth of (Ni, Fe)2P2X6 (X=S, Se) — •Tamara Holub, Yuliia Shemerliuk, Sebastian Selter, Saicharan Aswartham, and Bernd Buechner — Leibniz Institute for Solid State and Materials Research IFW, Institute for Solid State Research, 01069 Dresden

(NiFe)2P2X6 (X=S, Se) * magnetic material which belongs to the van der Waals family. These compounds are interesting, because of layered two dimensional structure. Here, we report on synthesis and crystal growth of (NiFe)2P2X6 (X=S, Se) by chemical vapor transport (CVT) -technique. Chemical vapor transport is characterized by the reaction of a solid material which volatilizes in the presence of a gaseous reactant and deposits elsewhere or at the cold end of the ampule in the form of single crystal. This (CVT) technique allows us to get high-quality single crystals, at the same time because of the closed system, the evaporation can be controlled. . As grown single crystals are further characterized with x-ray diffraction and SEM\EDX.

MA 42.50 Wed 15:00 P3

Investigating the CMR Effect in $Eu_5In_2Sb_6$ by Means of Nonlinear Transport and Fluctuation Spectroscopy Measurements — •Marvin Kopp[1], Merlin Mitschek[1], Priscila Rosa[2], Lennart Fox[1], and Jens Müller[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (Main), Germany — [2]Los Alamos National Laboratory, USA

The structures of Zintl phases illustrate a diversity of clusters, chains and other polyanionic frameworks and show air- and moisture sensitivity due to their components. Recently, air-stable heavy element analogues of the Zintl phases were synthesized as promising candidates for thermoelectric materials [1]. One of these new rare earth analogues is the antiferromagnetic system $Eu_5In_2Sb_6$, which is a narrow band gap semiconductor and shows a colossal magnetoresistance (CMR effect). At the Néel Temperature $T_N = 15\,K$, a sharp drop of the resistivity occurs on lowering the temperature and a strong suppression of the resistivity with applied magnetic field is observed, with magnetoresistance ratios of $-99.9\,\%$ at 15 K and 9 T. In order to test formation and percolation of magnetic polarons as a possible mechanism to explain the large negative magnetoresistive effect we have measured the third harmonic voltage signal giving access to the nonlinear transport, which is found to be non-zero around T_N. In addition we have performed fluctuation (noise) spectroscopy measurements showing a $1/f$-type behaviour of the noise power spectral density over a wide temperature range superimposed by distinct two-level fluctuations around T_N.
[1] J. Mater Chem. C, 2015, **3**, 10518.

MA 42.51 Wed 15:00 P3

strain-induced phase transition in CrI_3 bilayers — •Andrea Leon — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Recent reports on ferromagnetic and antiferromagnetic order in different 2D crystal Van der Waals heterostructures, have opened a vast field of possibilities for new physical phenomena and generation of electronic devices which already started to be explored experimentally. Among these materials, layered CrI_3 systems have been of great interest due to the staking dependent magnetism, mechanical/magnetic response under pressure, magnetoelectric and optical properties, between others. Motivated by this, the main goal of this work is to search for new electronic properties of antiferromagnetically coupled CrI_3 bilayer with C2/m symmetry under strain, using DFT calculations and analytic models. We found that strain may be an efficient tool to tune the magnetic phase of the structure. A tensile strain stabilizes the antiferromagnetic phase, while a compressive strain turns the system ferromagnetic. We understood that behavior by looking at the relative displacement between layers due to the strain. We also study the evolution of the magnetic anisotropy, the magnetic exchange coupling between Cr atoms, and how the Curie temperature is affected by the strain.

MA 42.52 Wed 15:00 P3

Induced moment mediated exchange couplings in transition metal systems — •Laszlo Udvardi[1,2] and Laszlo Szunyogh[1,2] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, Budafoki ut 8, H-1111 Budapest, Hungary — [2]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budafoki ut 8, H-1111 Budapest, Hungary

For a reliable description of the temperature dependent magnetic properties of transition metal alloys containing non-magnetic elements or thin magnetic films on non-magnetic substrates the exchange couplings mediated by the non-magnetic atoms must be included. In particular, in order to reproduce the proper gap due to the magnetic anisotropy in the magnetic excitation spectra of thin films, the effect of the induced moments on the substrate atoms must be taken into account. However, the direct inclusion of the exchange interaction between the magnetic and non-magnetic atoms introduces artificial dispersion-less bands in the magnon spectrum. In the present work a new procedure is developed to renormalize the exchange couplings between the magnetic atoms within the framework of the Korringa-Kohn-Rostoker Green-function method. The method is demonstrated for the temperature dependent magnetic anisotropy of ordered FePt alloy and for the magnon spectra of Fe layers on different non-magnetic substrates.

MA 42.53 Wed 15:00 P3

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

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

Unknown, highly non-linear functional relations can be modelled using neural networks with relative ease. In this contribution, we use a deep convolutional auto-encoder to predict the relationship between coil geometries and the respective magnetic fields. To achieve this, the current-path and the coil's magnetic field are presented to the neural network in spatially discretized form. By using the current-path as input and the magnetic field as output, the neural net is trained to find coil geometries, which produce a desired magnetic field. Furthermore, a neural net can be used as a surrogate model to speed up an iterative optimization approach in comparison to using a conventional simulation.

MA 42.54 Wed 15:00 P3

A reverse design methodology for 3-D induction coil windings — •Assja Laas[1] and Christian Schröder[1,2] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), University of Applied Sciences Bielefeld, Department of Engineering Sciences and Mathematics, Interaktion 1, D-33619 Bielefeld — [2]Faculty of Physics, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

In our study we focus on efficient design strategies for three-dimensional induction coils by exploiting an inverse methodology. Compact devices for inductive energy and information transfer require the design of appropriate non-conventional 3-D induction coils. For efficiency and energy reasons the geometry and topology of the coils needs to be adapted to the corresponding application. This is because inside the device there is only restricted space available for mounting the coil and, one is only interested in the near-field characteristics of the generated magnetic field. In our approach, we specify a target field over a certain region and approximate the generating current density through a Fourier series expansion. Because of the ill-posed nature of this problem, we use a Tikhonov regularization with a penalty term in order to calculate the unknown coefficients of the Fourier series expansion. We test our approach by reverse-calculating the windings of simple current carrying coil geometries, such as a circular loop and a linear wire, from their magnetic near-field distribution. Furthermore, we discuss the effect of different penalty terms on the obtained coil geometries and the accuracy of our approximation.

MA 42.55 Wed 15:00 P3

Light Induced Magnetisation Switching in Inversion Breaking Magnetic Materials — •Urmimala Dey[1,2], Oles Matsyshyn[1], and Inti Sodemann[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden 01187, Germany — [2]Indian Institute of Technology Kharagpur, Kharagpur 721302, India

We consider the effect of non-linear optical and transport electronic processes on the magnetisation dynamics in materials that break both inversion and time reversal symmetry, with particular focus on the interplay of Berry phases and non-linear processes such as the non-linear Hall effect and the shift and injection currents. In particular we describe an injection current process that is allowed when both of these symmetries are broken and that could facilitate optical control of magnetisation switching processes even with linearly polarised light. We will comment on potential material platforms to experimentally detect these effects.

MA 42.56 Wed 15:00 P3

Optimal control of magnetic states — Mohammad Badarneh[1], Grzegorz Kwiatkowski[1], and •Pavel Bessarab[1,2,3] — [1]University of Iceland, Reykjavík, Iceland — [2]ITMO University, St. Petersburg, Russia — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

Control of magnetization switching is of critical importance for the development of novel technologies based on magnetic materials. Transitions between stable magnetic states can follow various pathways which are not equivalent in terms of energy consumption and required time. In this study, we propose a general theoretical approach based on the optimal control theory to design pulses of external magnetic field for efficient switching between target magnetic states. The approach involves calculation of optimal control paths (OCPs) for the desired magnetic transition. Following an OCP involves rotation of magnetic moments in such a way that the strength of the external stimulus is minimized, but the system's internal dynamical modes are effectively used to aid magnetization switching. All properties of the switching pulses including temporal and spatial shape can be derived from OCPs in a systematic fashion. Various applications of OCP calculations are presented, including spin-wave assisted magnetization switching in nanowires and nucleation of magnetic skyrmions.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138), the Icelandic Reseach Fund (Grant No. 184949-052) and Alexander von Humboldt Foundation.

MA 43: Focus Session: Higher-Order Magnetic Interactions – Implications in 2D and 3D Magnetism I

Materials in which the magnetic moments order or cooperate in unusual ways underpin a plethora of physical phenomena, from strong magnetoelectric effects to topological quasiparticles, thus holding great promise for future spintronic and quantum computing applications. Magnetic interactions are the fundamental quantities that explain the complex magnetic phase diagrams and exotic excitation spectra of these intriguing materials. Recent theoretical and experimental developments have led to a realization of a pivotal role played by higher-order magnetic interactions in stabilizing intricate magnetic structures. The 4-spin 3-site interaction stabilizes an up-up-down-down state, which can become chiral. Theoretically, novel 4-spin chiral interactions and even 6-spin (chiral-chiral) couplings might explain the emergence of complex short-period 3D magnetic structures, and could open a path to the discovery of materials hosting 3D topological magnetization textures, such as magnetic hopfions. Experimentally, 4-spin interactions are conjectured to play a central role in skyrmions lattice formation in frustrated centrosymmetric materials. This area of research will make a strong impact in the field of magnetism in the upcoming years.

Organizers: Samir Lounis and Stefan Blügel (Forschungszentrum Jülich), Jonathan White (Paul Scherrer

Institut)

Time: Thursday 9:30–13:00 Location: HSZ 04

Invited Talk MA 43.1 Thu 9:30 HSZ 04
Magnetic vortices, skyrmions, and hedgehogs stabilized by long-range multiple-spin interactions — •Yukitoshi Motome — The University of Tokyo, Tokyo, Japan

Topological magnetic textures, such as vortices, skyrmions, and hedgehogs, have attracted numerous attention for the potential use of their magnetic, transport, and optical properties for future spintronics and quantum computing. For materializing such unconventional magnetism, it is crucially important to understand the relevant magnetic interactions. Widely known is the relativistic Dzyaloshinskii-Moriya interaction, which stabilizes swirling spin textures in competition with ferromagnetic exchange interactions. Here, we theoretically study another interactions working for more than two spins simultaneously. We show that such multiple-spin interactions naturally arise in itinerant magnets as higher-order contributions from the spin-charge coupling. They are intrinsically long-ranged with characteristic wave numbers specified by the Fermi surfaces, like the Ruderman-Kittel-Kasuya-Yosida interaction. We find that such long-range multiple-spin interactions can stabilize a variety of topological magnetic textures with unique features, even in centrosymmetric systems where the Dzyaloshinskii-Moriya interaction is absent: vortex crystals with chiral stripes, skyrmion crystals with a high topological number, unusual skyrmions in Rashba metals, and magnetic hedgehog lattices. We discuss our results with recent advances in experiments.

Invited Talk MA 43.2 Thu 10:00 HSZ 04
Formation of spin-hedgehog lattices and giant topological transport properties in chiral magnets — •Naoya Kanazawa — University of Tokyo, Tokyo, Japan

The last few years have seen remarkable progress in the discovery of versatile topological spin crystals with different topology, dimensionality and density. In parallel, the crucial role of higher-order magnetic interactions among multiple spins has been gradually recognized. In this talk, we report the formation of three-dimensional topological spin texture, i.e., the lattices of spin hedgehogs in a chiral magnet MnGe and its relatives. Their nature of twisting spins in short periods implies the relevance of such higher-order interactions. We also introduce various giant transport properties, such as topological Hall and thermoelectric effects, which may originate from the effective monopole field of spin hedgehogs. This work is done in collaboration with K. Akiba, T. Arima, R. Arita, S. Awaji, C. D. Dewhurst, Y. Fujishiro, M. Ichikawa, K. Ishizaka, H. Ishizuka, F. Kagawa, K. Kakurai, Y. Kawamura, M. Kawasaki, A. Kikkawa, S. Kimura, K. Kindo, T. Koretsune, A. Kitaori, Y. Kozuka, R. Kurihara, A. Matsuo, H. Mitamura, A. Miyake, D. Morikawa, T. Nakajima, A. Nakamura, N. Nagaosa, K. Ohishi, H. M. Rønnow, K. Shibata, T. Shimojima, J. Shiogai, Y. Taguchi, M. Tokunaga, Y. Tokura, A. Tsukazaki, V. Ukleev, J. S. White, X. Z. Yu.

Invited Talk MA 43.3 Thu 10:30 HSZ 04
Topological-chiral magnetic interactions driven by emergent orbital magnetism — •S. Grytsiuk[1], J.-P. Hanke[1], M. Hoffmann[1], J. Bouaziz[1], O. Gomonay[2], G. Bihlmayer[1], S. Lounis[1], Y. Mokrousov[1,2], and S. Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Based on microscopic arguments and a systematic total energy expansion, further validated by electronic structure calculations, we discover a new class of magnetic interactions of chiral nature originating from the so-called topological orbital moment (TOM) of electrons in noncoplanar magnets [1]. The TOMs, $\mathbf{L}^{\mathrm{TO}}$, emerge from the scalar spin chirality of three magnetic moments, $\mathbf{S}_i \cdot (\mathbf{S}_j \times \mathbf{S_k})$. As a result of a six-spin– or a four-spin interaction, they can interact with each other and interact with the spins of the underlying lattice. In the context of B20-type chiral magnet MnGe, these novel interactions can dominate over the Dzyaloshinskii-Moriya interaction in selecting the chiral ground state, providing possibly a key for solving the open question of the recently observed complex 3D magnetic structures. By providing a mechanism for the physical realization of the Faddeev model with hopfion solutions, topological-chiral interactions might play a key role in triggering the formation of 3D magnetic solitons without the assistance of an external magnetic field.

[1] S. Grytsiuk *et al.*, Nature Comm., accepted (2019); ArXiv:1904.02369

MA 43.4 Thu 11:00 HSZ 04
The chiral biquadratic pair interaction — •Sascha Brinker, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

The Dzyaloshinskii-Moriya interaction being chiral and driven by relativistic effects, leads to the stabilization of highly-noncollinear spin textures such as skyrmions, which thanks to their topological nature are promising building blocks for magnetic data storage and processing elements. Here, we reveal and study a new chiral pair interaction, $\vec{C}_{ij} \cdot (\vec{S}_i \times \vec{S}_j)(\vec{S}_i \cdot \vec{S}_j)$, which is the biquadratic equivalent of the Dzyaloshinskii-Moriya interaction. First, we derive this interaction and its guiding principles from a microscopic model, and we connect the atomistic form to the micromagnetic one. Second, we study its properties in the simplest prototypical systems, magnetic $3d$ transition metal dimers deposited on surfaces, resorting to systematic first-principles calculations. Lastly, we discuss its importance and implications not only for magnetic dimers but also for extended systems, namely one-dimensional spin spirals and complex two-dimensional magnetic structures, such as a nanoskyrmion lattice found in an Fe monolayer on Ir(111).
This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (ERC Consolidator Grant No. 681405 DYNASORE).

S. Brinker *et al.*, New J. Phys. **21**, 083015 (2019)

15 min. break.

Invited Talk MA 43.5 Thu 11:30 HSZ 04
How to understand the physics of complex spin structures — •Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Germany

The term "magnetism" subsumes a plethora of interactions originating from various physical mechanisms. Their competition often results in highly complex spin structures, such that the specific origin is masked and can only be unraveled by combining experiment and theory. For example, for an Fe monolayer on Rh(111) an up-up-down-down (↑↑↓↓) spin structure was predicted by DFT [1] which was only later understood to originate from the previously unconsidered four-spin–three-site beyond-Heisenberg interaction [2]. We could indeed confirm this ↑↑↓↓ spin structure experimentally by spin-polarized STM. Three orientational domains were observed, the field-dependent behavior of which is surprisingly complex, potentially due to uncompensated spins at domain boundaries. Furthermore, in a recent survey of submonolayer transition metal oxides on Ir and Pt(001) we observed highly complex spin structures which appears to be driven by a Dzyaloshinskii-Moriya-enhanced Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction [3]. However, the orientation of the Dzyaloshinskii-Moriya vector and the observation of a long-wavelength spin rotation have not yet been adequately explained [4].
[1] A. Al-Zubi *et al.*, Phys. Status Solidi B **248**, 2242 (2011)
[2] A. Krönlein *et al.*, Phys. Rev. Lett. **120**, 207202 (2018)
[3] M. Schmitt *et al.*, Nature Comm. **10**, 2610 (2019)
[4] M. Schmitt *et al.*, Phys. Rev. B **100**, 054431 (2019)

MA 43.6 Thu 12:00 HSZ 04
Discovery of a triple-Q state in an ultrathin transition-metal film — Jonas Spethmann[1], Sebastian Meyer[2], Kirsten von Bergmann[1], Soumyajyoti Haldar[2], Jonas Sassmannshausen[1], •Stefan Heinze[2], Roland Wiesendanger[1], and André Kubetzka[1] — [1]Department of Physics, University of Hamburg, 20355 Hamburg, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098 Kiel, Germany

Higher-order exchange interactions have been proposed based on the Hubbard model [1-3]. These terms can stabilize intriguing magnetic ground states due to a superposition of spin spirals. A prominent example is the triple-Q state predicted for a Mn monolayer on Cu(111) [4]. Here, we experimentally verify the existence of two – previously predicted but so far unobserved – magnetic ground states in a Mn monolayer on the Re(0001) surface using spin-polarized scanning tunneling microscopy. For fcc stacking of Mn the row-wise antiferromagnetic state occurs, while for hcp-Mn a superposition of three row-wise antiferromagnetic states, the triple-Q state, appears. Density functional theory calculations elucidate the subtle interplay of different magnetic interactions to form these spin structures and provide insight into the role played by relativistic effects.

[1] M. Takahashi, J. Phys. C Solid State Phys. **10**, 1289 (1977)
[2] A. H. MacDonald *et al.*, Phys. Rev. B **37**, 9753 (1988)
[3] M. Hoffmann and S. Blügel, arXiv:1803.01315 (2018)
[4] P. Kurz *et al.*, Phys. Rev. Lett. **86**, 1106 (2001).

MA 43.7 Thu 12:15 HSZ 04

Isotropic four-spin interactions in magnetic trimers — •Andras Laszloffy[1,2], Bendeguz Nyari[2], and Laszlo Szunyogh[2] — [1]Wigner Research Center for Physics, Budapest, Hungary — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary

Recently a rapidly growing interest emerged in investigating the role of higher order spin interactions, both the SU(2) invariant and the chiral ones. In this contribution we study the effect of four-spin interactions along selective paths in the spin-configuration space of magnetic trimers. In order to calculate the SU(2) invariant four-spin interactions we use a Green's function perturbation scheme, where the spinless part of the Hamiltonian defines the unperturbed system, while the spin-dependent part of the Hamiltonian is treated as perturbation. Two-spin and four-spin interactions can then be obtained in second and fourth order perturbation of the Green's function. We demonstrate how the four-spin interactions enter the spin-model parameters obtained from the method of infinitesimal rotations leading to spurious tensorial two-spin interactions. The theory can be straightforwardly implemented in the Korringa-Kohn-Rostoker Green's function technique and in terms of this method we perform calculations for Cr and Mn trimers deposited on heavy metal surfaces. Comparing the energy obtained from the spin model with direct calculations of the band energy proves that the inclusion of the four-spin interactions significantly increases the accuracy of the spin-model description of the magnetic clusters under consideration.

MA 43.8 Thu 12:30 HSZ 04

First-principles multispin interactions and their impact on magnetic properties — •Sergiy Mankovsky, Svitlana Polesya, Alberto Marmodoro, Eszter Simon, and Hubert Ebert — Dept. Chemistry, LMU Munich, Butenandtstrasse 11, D-81377 Munich, Germany

We discuss the impact of interatomic exchange interactions on magnetic properties beyond the classical Heisenberg model. These extensions include the Dzyaloshinskii-Moriya interaction (DMI), biquadratic (chiral and non-chiral), three-spin and four spin interaction, which can be calculated from first principles on the basis of the fully relativistic Korringa-Kohn-Rostoker (KKR) Green function method. In particular, the role of the non-chiral biquadratic interactions will be discussed in connection to the spin-wave stiffness and critical temperature of magnetic materials. We will discuss also the impact of the higher-order chiral exchange interactions on the formation of skyrmion magnetic structures which is often attributed to the effect of the DMI competing with the isotropic exchange and external magnetic fields. We will discuss also the possibility of an external electric field to tune the exchange interactions with an emphasis on the DMI, and accordingly discuss its impact on the Skyrmion formation.

MA 43.9 Thu 12:45 HSZ 04

Role of higher-order exchange interactions for skyrmion stability — •Souvik Paul, Soumyajyoti Haldar, Stephan von Malottki, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Germany

Magnetic skyrmions have recently become a research focus as they show promise for future magnetic memory and logic devices. One key obstacle for applications is the stability of skyrmionic bits against thermal fluctuations. The importance of Heisenberg exchange interaction, Dzyaloshinskii-Moriya interaction, magnetocrystalline anisotropy and dipole-dipole interactions in skyrmion stability has been reported. However, due to their origin from a fourth-order perturbation theory, non-Heisenberg higher-order exchange interactions (HOI) – the biquadratic, the three-site-four-spin and the four-site-four-spin interaction – have so far been neglected. Using *ab-initio* parametrized atomistic spin dynamics simulations for ultrathin films, we demonstrate that the HOI play an important role for skyrmion stability. We find that the effect of the first two HOI, to a large extent, can be included in the effective Heisenberg exchange constants. However, the four-site four spin interaction behaves qualitatively in a different way and has a large contribution on the energy barrier stabilizing skyrmions and antiskyrmions against annihilation. Our study opens up a new avenue to increase the stability of topological spin structures.

MA 44: Surface Magnetism (joint session MA/O)

Time: Thursday 9:30–12:00 Location: HSZ 101

Invited Talk MA 44.1 Thu 9:30 HSZ 101

Vacuum Resonance States as Atomic-Scale Probes of Noncollinear Surface Magnetism — •Anika Schlenhoff — Department of Physics, University of Hamburg (Germany)

Understanding the spin-dependent scattering of electrons at magnetic surfaces is highly relevant for the control of electron transport in future spintronic applications. However, its atomic-scale variations, e.g. on noncollinear magnetic surfaces, remained inaccessible, due to the laterally averaging nature of the established experimental approaches.

By means of spin-polarized scanning tunneling microscopy (SP-STM) and spectroscopy on unoccupied resonance states (RSs) located *in vacuo*, the reflection of electrons at noncollinear magnetic surfaces is investigated [1]. Even for energies up to 20 eV above the Fermi level, the RSs exhibit the same local spin quantization axis as the underlying spin texture. Mapping the spin-dependent electron phase shift upon reflection at the surface on the atomic scale demonstrates the relevance of all magnetic ground state interactions for the scattering of spin-polarized low-energy electrons. Moreover, while conventional SP-STM is restricted to probe at tip-sample distances of a few Å, tunneling into RSs allows for imaging atomic-scale spin textures at technically feasible distances in the nm regime [2]. Experimental results will be discussed in terms of the RS spin-splitting and the magnetic contrast as a function of bias and tip-sample distance, as well as in terms of the atomic-scale nature of the electron reflection at the surface.

[1] A. Schlenhoff, S. Kovaric, S. Krause, and R. Wiesendanger, Phys. Rev. Lett. **123**, 087202 (2019). [2] A. Schlenhoff *et al.*, in preparation.

MA 44.2 Thu 10:00 HSZ 101

Dead magnetic layer at the interface - magnetic moment quenching in Mn on W(001) — •Sebastian Meyer[1], Martin Schmitt[2], Matthias Vogt[2], Matthias Bode[2], and Stefan Heinze[1] — [1]Institute for Theoretical Physics and Astrophysics, Christian-Albrechts University of Kiel, 24098 Kiel — [2]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, 97074 Würzburg

The magnetic moment of transition metals can vary strongly due to orbital bonding interactions with ligands, hybridization, or band structure changes induced by reduced coordination, often resulting in high spin–low spin transitions [1]. In contrast, the complete quenching of the magnetic moment, a so-called "dead magnetic layer", has not yet been observed [2]. Using density functional theory in combination with spin-polarized scanning tunneling microscopy, we show that the surface of a Mn double layer on W(001) exhibits a two-dimensional c(2×2) antiferromagnetic ground state. This result can only be confirmed by a complete moment quenching in the interfacial Mn layer caused by the combined action of hybridization and magnetic frustration.

[1] J. L. Fry, *et. al.*, Phys. Rev. B **36**, 868 (1987)
[2] C. A. F. Vaz, *et. al.*, Rep. Prog. Phys. **71**, 056501 (2008)

MA 44.3 Thu 10:15 HSZ 101

Tunneling anisotropic magnetoresistance of Pb and Bi adatoms and dimers on Mn/W(110) — •Soumyajyoti Haldar, Mara Gutzeit, and Stefan Heinze — Institute of Theoretical Physics, University of Kiel, Leibnizstrasse 15, 24098 Kiel, Germany

Noncollinear magnetic structures at transition-metal interfaces are very promising candidates for spintronics applications [1]. A Mn monolayer on W(110) is a prominent example which exhibits a noncollinear cycloidal spin-spiral ground state with an angle of about 173° between neighboring spins. This allows to rotate the spin-quantization axis of an adatom or dimer quasicontinuously and is ideally suited to explore the angular dependence of the tunneling anisotropic magnetoresistance (TAMR) using scanning tunneling microscopy. Here [2], using density functional theory, we explored the TAMR effect of Pb and Bi adatoms and dimers adsorbed on this surface as these elements have a very strong spin-orbit coupling. Pb and Bi adatoms and dimers show a large TAMR up to 60% due to strong spin-orbit coupling (SOC) and the hybridization of 6*p* orbitals with 3*d* states of the magnetic layer. For dimers the TAMR also depends sensitively on the dimer orientation with respect to the crystallographic directions of the surface due to bonds formation with the surface and the symmetry of the SOC induced mixing.
[1] A. Fert et al. Nat. Nanotechnol. **8**, 152 (2013). [2] S. Haldar et al. Phys. Rev. B **100**, 094412 (2019)

MA 44.4 Thu 10:30 HSZ 101

Dynamical spin-excitations of transition metal atoms deposited on superconducting surfaces — •Ana Montero, Filipe Souza Mendes Guimarães, Juba Bouaziz, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Recently, the interest in superconductors has been renewed thanks to their application in topological quantum computing — for instance, in the context of qubits, such as Majorana zero modes, which are in-gap states that can arise in nanostructures deposited atop superconductors. Based on ab-initio simulations [1], we systematically scrutinize the electronic and magnetic properties of 3*d* adatoms deposited on various superconducting surfaces above their critical temperature, and investigate their dynamical spin-excitation as probed via inelastic tunneling spectroscopy (IETS). The excitation lifetime, damping and signature in the transport spectra will be presented with a focus on the potential generation of many-body states resulting from the interaction of electrons and spin-excitations.
This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).
[1] B. Schweflinghaus et al. Phys. Rev. B **89**, 235439 (2014).

MA 44.5 Thu 10:45 HSZ 101

Doping graphene with substitutional manganese atoms — •Renan Villarreal[1], Pin-Cheng Lin[1], Harsh Bana[1], Maya N. Nair[2], Ken Verguts[3,4], Steven Brems[4], Stefan De Gendt[3,4], Manuel Auge[5], Hans Hofsäss[5], Chris Van Haesendonck[1], and Lino M. C. Pereira[1] — [1]Quantum Solid-State Physics, KU Leuven, 3001 Leuven, Belgium — [2]CUNY Advanced Science Research Centre, 85 St. Nicholas Terrace, New York, N.Y. 10031, USA — [3]Departement Chemie, KU Leuven, 3001 Leuven, Belgium — [4]Interuniversitair Micro-electronica Centrum (imec), vzw, 3001 Leuven, Belgium — [5]II. Institute of Physics, University of Göttingen, Göttingen 37077, Germany

Several approaches have been explored for the functionalization of 2D materials: the use of different substrates, creation of intrinsic defects, adsorption and intercalation, substitutional doping, among others. For incorporation of substitutional dopants, a major challenge remains: the limited control over the concentration and form of incorporation. An alternative approach is to incorporate the foreign species by ultra-low energy (ULE) ion implantation, precisely tuning the number of implanted ions and their kinetic energy. Here, we demonstrate that it is possible to controllably incorporate manganese (Mn) in graphene as a substitutional dopant using ULE ion implantation. Our approach is based on a wide range of characterization techniques, including STM/STS, synchrotron-based XPS, ARPES, XMCD, transport measurements and Raman spectroscopy. These experimental studies are complemented by DFT and MD calculations.

15 min. break.

MA 44.6 Thu 11:15 HSZ 101

Growth and Characterization of Thulium-Cyclooctatetraene-Compounds on Gr/Ir(111) with XANES and XMCD — •Lea Spieker[1], Alexander Herman[1], Benedikt Eggert[1], Tobias Lojewski[1], Nico Rothenbach[1], Stefan Kraus[2], Florin Radu[3], Chen Luo[3,4], Kai Chen[3], Fadi Choueikani[5], Thomas Michely[2], and Heiko Wende[1] — [1]University of Duisburg-Essen — [2]University of Cologne — [3]Helmholz Center Berlin for Materials and Energy — [4]TU Munich — [5]Synchrotron SOLEIL

The magnetic anisotropy and the magnetic coupling of localised 4f elements connected to an organic ligand in a molecular network are a notable point of interest in organic spintronics. We combine the lanthanide thulium (Tm) with the organic molecule cyclooctatetraene (Cot) for the growth of different phases on Gr/Ir(111). Using an undoped substrate Gr/Ir(111) leads the TmCot to self-assemble in a punctiform shape (Dot-phase). On the negatively doped substrate Gr/Eu/Ir(111) TmCot self-assembles in sandwich-molecular wires. As reference, these phases are compared to the metallic sample Tm/Ir(111) which is known to have an electronic configuration of $4f^{12}$. The electronic and magnetic properties are analysed by X-ray Absorption Spectroscopy using the methods XANES and XMCD, at temperatures down to 1 K. Angular- and field-depended measurements at the thulium $M_{4,5}$-edge revealed magnetic anisotropies. By comparison to multiplet calculations the electronic configuration could be determined as $4f^{12}$ for the three phases. Financial support by DFG (WE 2623/17-1) is acknowledged.

MA 44.7 Thu 11:30 HSZ 101

***Ab initio* simulations of hybrid magnetic 2D-materials** — •Nicolae Atodiresei, Vasile Caciuc, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich, Germany

We used density functional theory calculations to engineer the electronic and magnetic properties for two classes of two dimensional (2D) materials adsorbed onto Ir(111). In a 1st study, we investigated how to magnetically functionalize a nonmagnetic 2D system as MoS_2 by adsorbing a magnetic cluster made of three Fe atoms. In a 2nd study, we employed non-magnetic molecular systems characterized by different reactivity (e.g. electropositive BH_3 and electronegative NH_3 molecules) to chemically funtionalize a single layer of a magnetic 2D system such as CrI_3. Our *ab initio* simulations can be used as a guide on how the interaction between 2D, atomic clusters and molecules can be used to manipulate the (i) spin-polarization, (ii) magnetic exchange couplings, (iii) magnetic moments and (iv) their orientation of these hybrid 2D materials. This work has been supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project number 277146847 - CRC 1238 (C01). [1] V. Caciuc *et al.*, Phys. Rev. Mat. **2**, 084001 (2018). [2] V. Caciuc *et al.*, Phys. Rev. Mat. **3**, 094002 (2019).

MA 44.8 Thu 11:45 HSZ 101

Emerging 2D-ferromagnetism and strong spin-orbit coupling at the surface of valence-fluctuating $EuIr_2Si_2$ — •Susanne Schulz[1], Ilya A. Nechaev[2], Monika Güttler[1], Georg Poelchen[1], Steffen Danzenbächer[1], Silvia Seiro[3], Kristin Kliemt[4], Evgueni V. Chulkov[5], Clemens Laubschat[1], Eugene E. Krasovskii[5], Christoph Geibel[6], Cornelius Krellner[4], Kurt Kummer[7], and Denis V. Vyalikh[5] — [1]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [2]Centro de Física de Materiales CFM-MPC and Centro Mixto CSIC-UPV/EHU, Donostia/San Sebastián, Spain — [3]IFW Dresden, Germany — [4]Kristall- und Materiallabor, Goethe-Universität Frankfurt, Germany — [5]Donostia International Physics Center, Donostia/San Sebastián, Spain — [6]MPI für Chemische Physik fester Stoffe, Dresden, Germany — [7]European Synchrotron Radiation Facility, Grenoble, France

Here, we present the valence-fluctuating material $EuIr_2Si_2$, where in contrast to its non-magnetic bulk, the Si-terminated surface reveals controllable 2D ferromagnetism. Close to the surface the Eu ions prefer a magnetic divalent configuration and their large 4*f* moments order below 48 K. The emerging exchange interaction modifies the spin polarization of the 2D surface electrons originally induced by the strong Rashba effect. The temperature-dependent intermediate valence of the bulk allows to tune the energy and momentum size of the projected band gaps to which the 2D electrons are confined. This gives an additional degree of freedom to handle spin-polarized electrons at the surface.

MA 45: Magnonics I

Time: Thursday 9:30–13:00 Location: HSZ 401

MA 45.1 Thu 9:30 HSZ 401

Propagation of coherent spin waves in individual nano-sized yttrium iron garnet magnonic conduits — •B. Heinz[1,2], T. Brächer[1], M. Schneider[1], Q. Wang[1], B. Lägel[3], A. M. Friedel[1], D. Breitbach[1], S. Steinert[1], T. Meyer[4], M. Kewenig[1], C. Dubs[5], P. Pirro[1], and A. V. Chumak[1,6] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Nano Structuring Center, TU Kaiserslautern, Germany — [4]THATec Innovation GmbH, Germany — [5]INNOVENT e.V., Technologieentwicklung Jena, Germany — [6]Faculty of Physics, University of Vienna, Austria

Modern-days CMOS-based computation technology is reaching fundamental limitations. A promising path to overcome these limitations is the emerging field of magnonics which utilizes spin waves for data transport. However, the feasibility of this technology essentially relies on the scalability to the nanoscale and a proof that coherent spin waves can propagate in these structures. Here, we present a study of the spin-wave dynamics in individual yttrium iron garnet (YIG) magnonic conduits with lateral dimensions down to 50 nm. Space and time resolved micro-focused Brillouin-Light-Scattering spectroscopy is used to directly measure the spin-wave decay length and group velocity. Thereby, the first experimental proof of propagating spin waves in individual nano-sized YIG conduits is demonstrated. We acknowledge funding by ERC Starting Grant 678309 MagnonCircuits, DFG Grant DU 1427/2-1 and the Graduate School Material Science in Mainz.

MA 45.2 Thu 9:45 HSZ 401

Realization of a nanoscale magnonic directional coupler for all-magnon circuits — •Qi Wang[1], Martin Kewenig[1], Michael Schneider[1], Roman Verba[2], Björn Heinz[1,3], Moritz Geilen[1], Morteza Mohseni[1], Bert Lägel[4], Florin Ciubotaru[5], Christoph Adelmann[5], Carsten Dubs[6], Sorin Cotofana[7], Thomas Brächer[1], Philipp Pirro[1], and Andrii Chumak[1,8] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institute of Magnetism, Kyiv, Ukraine — [3]Graduate School Materials Science in Mainz, Mainz, Germany — [4]Nano Structuring Center, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [5]Imec, Leuven, Belgium — [6]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [7]Department of Quantum and Computer Engineering, Delft University of Technology, Delft, The Netherlands — [8]Faculty of Physics, University of Vienna, Vienna, Austria

Magnonics is a promising alternative in view of beyond-Moore computing in which information is carried by magnons instead of electrons. However, the major challenge in magnon-based computing is the transition from a single logic unit to an integrated circuit. Here, we report a nanoscale directional coupler fabricated from an 85 nm thick Yttrium Ion Garnet film, which consists of two coupled waveguides with a width of 350 nm separated by a gap of 320 nm. The directional coupler can be used as a universal unit for all-magnon circuits, working as a multiplexer, a AND gate and an XOR gate. These functions are demonstrated by Brillouin light scattering spectroscopy.

MA 45.3 Thu 10:00 HSZ 401

Investigation of spin wave focusing by a magnetic field gradient — •Philipp Geyer[1], Rouven Dreyer[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Nanotechnikum Weinberg, 06120 Halle (Saale), Germany

Magnonics is a promising field to realize low energy information transmission and processing. It has been shown experimentally, that spin waves passing through a lateral thickness variation in a magnetic thin film obey snell's law [1]. So, a spatial change of the dispersion parameters like film thickness [2] or magnetic field can be used to deflect and focus a plane spin wave. We show that a magnetic field gradient can be induced using the demagnetizing field of a localized, lateral confinement inside an YIG film. Already a simple rectangular constriction can be used to create a spin wave interference pattern, which focuses the incident spin wave and remain stable when changing the external magnetic field or excitation frequency. It should be noted that the intensity at the focus is higher than at the position of the lens which was not observed in past experiments. The lens shape was first investigated using micromagnetic simulations with MuMax3. The fabricated lenses and their performance were characterized with spatially and time resolved magneto-optical Kerr microscopy (TR-MOKE) measurements.

[1] J. Stigloher et al., Phys. Rev. Lett. 117, 037204 (2016) [2] J. Toedt et al., Scientific Reports 6, 33169 (2016)

MA 45.4 Thu 10:15 HSZ 401

Dynamic Unidirectional Magnetic Anisotropy due to Chiral Magnetic Coupling — •Nicolas Josten[1], Benjamin Zingsem[1], Thomas Feggeler[1], Ralf Meckenstock[1], Detlef Spoddig[1], Marina Spasova[1], Ke Chai[2], Iliya Radulov[3], Zi-An Li[2], Oliver Gutfleisch[3], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg Essen, Duisburg, 47057, Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — [3]Department of Material- and Geosciences, Functional Materials, Technical University Darmstadt, Germany

Non-centrosymmetric crystal structures like cubic FeGe show an antisymmetric exchange often denoted as Dzyaloshinskii-Moriya interaction (DMI). In addition to static spin structures like helices or skyrmions DMI leads to a shift of the dispersion curve. We investigated the dynamic magnetic properties of millimeter and micrometer sized polycrystalline FeGe samples using resonator-based X-band and K-band ferromagnetic resonance (FMR). The measurements reveal unidirectional anisotropy [1], i.e. a change of the resonance position of up to 30 mT after inversion of the magnetic field direction. This difference is present at all investigated temperatures (80K - 280K), frequencies and sample sizes.

[1] N. Josten et al., Dynamic unidirectional anisotropy in cubic FeGe with antisymmetric spin-spin-coupling, submitted to Scientific Reports.

MA 45.5 Thu 10:30 HSZ 401

Reflection-less width-modulated magnonic crystals — •Pascal Frey[1], Aleksei A. Nikitin[2], Alexey B. Ustinov[2], Florin Ciubotaru[3], Andrii V. Chumak[4], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physical Electronics and Technology, St. Petersburg Electrotechnical University, 197376 St. Petersburg, Russia — [3]imec, B-3001 Leuven, Belgium — [4]Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Vienna, Austria

Magnonic crystals receive a lot of attention in spintronics, due to their great potential for information processing technologies. The main features of these crystals are the presence of bandgaps in the spin-wave spectra. The bandgaps are formed due to Bragg reflections from the artificially created periodic structures. In this work, we studied spin-wave propagation in longitudinally magnetized width-modulated yttrium-iron-garnet waveguides by means of both Brillouin light scattering and microwave spectroscopies. Short pulses (30 ns) of backward volume magnetostatic spin waves were excited, close to the ferromagnetic resonance frequency, and their propagation was visualized and measured, both in pass and rejection frequency bands. We found, that the width-modulated magnonic crystal, shows a new underlying mechanism, where no back reflection of the spin-wave pulse is observed. Such a reflection-less magnonic crystal is a promising candidate for the realization of frequency selective or multi-component devices.

15 min. break.

MA 45.6 Thu 11:00 HSZ 401

Frequency multiplication effects in thin ferromagnetic layers detected by diamond nitrogen-vacancy center microscopy — •Chris Körner, Rouven Dreyer, Niklas Liebing, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, 06120 Halle, Germany

In thin ferromagnetic layers inhomogeneous magnetic properties can lead to frequency multiplication effects generating high harmonics of the rf driving field close to ferromagnetic resonance. Scanning time-resolved Kerr microscopy is employed to spatially resolve those high harmonics as well as parametric excitations [1]. Since the spatial frequency of the magnetic response increases at higher harmonics, the diffraction limited resolution of the microscope leads to an averaging of the Kerr response within the laser spot. Hence, a more local probing technique is required to resolve magnetization dynamics. Because of their extremely small size and strong response to magnetic fields, Nitrogen-vacancy defect centers in diamond offer an ideal method to detect fields locally. The optical detection of magnetic resonance (ODMR) is a double-resonant technique to locally probe magnetic fields with the help of those defect centers [2]. It allows for the detection of up to the 25th harmonic of the rf excitation frequency generated by the precessing magnetic moments in a Permalloy film at low magnetic bias fields as well as parametric excitations at large driving amplitudes.

[1] R. Dreyer et al. ArXiv:1803.04943 (2018)
[2] C. S. Wolfe et al. ArXiv 1512.05418v2 (2016)

MA 45.7 Thu 11:15 HSZ 401

Probing magnetic excitation by spin-polarized scanning tunneling microscopy — •Hung-Hsiang Yang[1,2], Masayuki Hamada[1], Yasuo Yoshida[1], and Yukio Hasegawa[1] — [1]Institute for Solid State Physics, 5-1-5, Kashiwa-no-ha, Kashiwa, Chiba 277-8581, Japan — [2]Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, Karlsruhe, 76131, Germany

Magnetic excitation due to inelastic electron scattering plays a crucial role in spintronics devices concerning the spin lifetime of polarized electrons and the amount of spin transfer torque for switching magnetic configurations in magnetic tunnel junctions. One of the fundamental processes is magnon creation, which occurs when injected hot electrons induce spin-flip scattering of the magnetic material. To image and address the magnetic origin of the excitations, we have performed low-temperature spin-polarized inelastic electron tunneling spectroscopy (IETS) on double layer Mn thin films formed on W(110) substrate. The atomically-thin magnetic layer exhibits a homogeneous spin spiral with antiferromagnetic coupling, which provides a good reference for spin-polarized scanning tunneling microscopy (STM). Characteristic peak-dip feature in IETS, as well as its correlation with the spin spiral, are acquired. Additionally, we have observed contrast reversal in the IETS intensity when the tip magnetization direction is flipped, indicating that the excitation is spin-dependent and thus presumably due to magnon creation. The spatial distribution of the magnon excitation and its energy dependence will be discussed in the presentation.

MA 45.8 Thu 11:30 HSZ 401

Non-standing spin-waves in confined micron-sized structures imaged with time-resolved STXM — •Santa Pile[1], Taddäus Schaffers[1], Sven Stienen[2], Martin Buchner[1], Sebastian Wintz[3], Sina Mayr[4], Johannes Förster[3], Verena Ney[1], Rysard Narkowicz[2], Kilian Lenz[2], Markus Weigand[5], Jürgen Lindner[2], and Andreas Ney[1] — [1]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, 4040 Linz, Austria — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [4]Paul Scherrer Institute, Villigen PSI, Switzerland — [5]Helmholtz-Zentrum Berlin, Berlin, Germany

The STXM-FMR setup enables the visualization of the high frequency magnetization dynamics in the GHz regime with a high lateral resolution of nominally 35 nm and a time resolution of 17.4 ps [1]. In this contribution we present the results for the magnetic $Ni_{80}Fe_{20}$ micron-sized stripes with dimensions: 5x1x0.03 μm^3. For FMR and STXM-FMR measurements a static magnetic field was applied in the plane of the stripes. Both FMR and STXM-FMR measurements confirm that quasi-uniform and spin-wave modes can be excited in the samples. With increasing the static magnetic field it is possible to observe the transition from one mode to another and also a superposition of the modes in-between the FMR signals, when a non-standing character of the spin-waves is visible. Financial support by the Austrian Science Fund (FWF), Project No. I-3050 is gratefully acknowledged.

[1] T. Schaffers et al., Nanomaterials 9, 940 (2019).

MA 45.9 Thu 11:45 HSZ 401

Detection of magnons in thin ferromagnetic films by ferromagnetic resonance measurements — •Sergej Andreev, Julian Braun, Elke Scheer, and Torsten Pietsch — Physics Department, University of Konstanz, 78457 Konstanz, Germany

We report measurements of the ferromagnetic resonance (FMR) of thin ferromagnetic films and bilayers of Ni, Co, Py and NiCo by FMR measurements in a broadband resonator from 2 to 40 GHz with an applied magnetic field in plane at 4 K and deduce their spin wave spectra from these data. We obtain information on the magnetization and the Gilbert damping of perpendicular polarized magnons. Superimposed onto the spin wave absorption lines, we observe an amplification of the FMR signal with a Fano resonance shape at distinct frequencies, which are absent without the ferromagnetic fields. We interpret this finding as an enhancement and modification of the resonator properties by the coupling to the ferromagnetic layer.

MA 45.10 Thu 12:00 HSZ 401

Phase-sensitive and Spatially Resolved Detection of Magnetization Dynamics — •Lukas Liensberger[1,2], Luis Flacke[1,2], David Rogerson[1,2], Matthias Althammer[1,2], Rudolf Gross[1,2,3], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Germany — [2]Physik-Department, Technische Universität München, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Germany

In the recent years, many advances in utilizing spinwaves and their quanta, magnons, have been made in order to transport and store information. The precise and accurate determination of dynamic magnetic properties like magnetic damping and spinwave propagation length is essential to design magnonic devices. The established broadband ferromagnetic resonance spectroscopy with a vector network analyzer (BMR) is the key technique to determine damping characteristics in unpatterned samples. It however lacks the ability to measure the magnetization dynamics locally and to detect propagating spinwaves with non-zero wavenumber.

Here, we establish the micro-focused frequency-resolved magneto-optic Kerr effect (μFR-MOKE), which is essentially a spatially resolved BMR technique with sub-micrometer resolution. We present μFR-MOKE studies of propagating micrometer-scale spinwaves in microstructured ferromagnet/normal metal samples with $Co_{25}Fe_{75}$ as the ferromagnet and compare the μFR-MOKE results to those obtained using established micro-focused Brillouin light scattering. We acknowledge financial support by the DFG via project WE5386/4-1.

MA 45.11 Thu 12:15 HSZ 401

Threshold determination of non-linear spin-wave generation at low magnetic bias field — •Rouven Dreyer, Niklas Liebing, Chris Körner, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

Recently it was shown that the prediction of the non-linear spin-wave excitation in the framework of Suhl instability processes is not adequate at low magnetic bias fields. In particular, it was shown by spatially averaged and time-resolved x-ray ferromagnetic resonance spectroscopy that in the low bias field regime non-linear spin waves are excited parametrically at 3/2 of the excitation frequency [1].

Here we demonstrate the 3/2 ω non-linear spin-wave (NLSW) generation in $Ni_{80}Fe_{20}$ microstructures using a novel variant of scanning magneto-optical microscopy which we term super-Nyquist sampling microscopy (SNS-MOKE) [2]. This technique allows for phase-resolved imaging of the sample at multiple arbitrary frequencies. In this way we detect parametrically excited NLSWs at 3/2 of the excitation frequency in space and time directly. For this type of non-linearities we determine the threshold rf-field for different sample geometries and investigate the phase stability of the NLSW generation as a function of rf-field and bias field. The corresponding wave vectors obtained from the 2D-FFT of the observed spatially resolved spin-wave pattern at 3/2 ω above the threshold rf-field are in agreement with the predictions from Bauer et al. [1]. [1] H. G. Bauer et al., Nat. Commun. 6:8274 (2015) [2] R. Dreyer et al., arXiv:1803.04943 (2018)

MA 45.12 Thu 12:30 HSZ 401

Generation and tuning of a spin wave frequency comb — •Tobias Hula[1], Luis Flacke[2,3], Lukas Liensberger[2,3], M Copus[4], Katrin Schultheiss[1], Aleksandr Buzdakov[1], Mathias Weiler[2,3], Robert Camley[4], and Helmut Schultheiss[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Walther-Meißner-Institute, Bayerische Akademie der Wissenschaften, Garching, Germany — [3]Physik-Department, Technische Universität München, Munich, Germany — [4]Center for Magnetism and Magnetic Nanostructures, University of Colorado, Colorado Springs, USA

We present experimental results on the generation of a spin wave frequency comb in a Co25Fe75 wave guide measured by Brillouin light scattering microscopy. By driving the magnetisation at large precession angles, using high RF amplitudes, non-linear four magnon scattering can be observed. When mixing two RF signals with different frequencies and amplitudes, we can actively control the final states that will be populated by this scattering process. Our results show the generation of a frequency comb consisting of several spin waves with tuneable frequency spacing and amplitude. This effect is investigated in different sample geometries, which allow mixing of co-propagating as well as counter-propagating spin waves. Our experimental observations are in qualitative agreement with micromagnetic simulations.

Financial support by the Deutsche Forschungsgemeinschaft within programs SCHU2922/1-1 and WE 5386/4-1 is gratefully acknowledged. K.S. acknowledges funding within the Helmholtz Postdoc Programme.

MA 45.13 Thu 12:45 HSZ 401

Spin wave excitation by surface acoustic waves — •Moritz Geilen[1], Felix Kohl[1], Alexandra Nicoloiu[2], Florin Ciubotaru[3], Christoph Adelmann[3], Alexandru Müller[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]IMT, Bucharest, Romania — [3]IMEC, Leuven, Belgium

Surface acoustic waves (SAW) are strain waves which are located close to the surface of a medium. They are widely used in bandfilters up to the GHz regime because of their tuneability and narrow bandwidth given by wavevector selection during excitation and detection. Is a magnetic film placed on the surface of the medium an effective field is generated by the magnetoelastic interaction. This field can be used to excite spin waves. We present the investigation on spin wave excitation in a CoFeB microstripe on top of a GaN layer. Both, the SAWs and the spin waves, have been measured by Brillouin light scattering microscopy. With this technique spatially resolved measurements are possible while the signals caused by phonons and magnons can be well separated by the polarization of the scattered light. We found that spin waves can be excited in a wide wavevector regime. We acknowledge the support of the EU under H2020 FET Open Project CHIRON (grant agreement no 692519 2018 - 2021).

MA 46: Spin: Transport, Orbitronics and Hall Effects I

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

MA 46.1 Thu 9:30 HSZ 403

Long-range phonon spin transport in ferromagnet - nonmagnetic insulator heterostructures — •Andreas Rückriegel[1] and Rembert A. Duine[1,2] — [1]Institute for Theoretical Physics and Center for Extreme Matter and Emergent Phenomena, Utrecht University, Utrecht, The Netherlands — [2]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

We investigate phonon spin transport in an insulating ferromagnet - nonmagnet - ferromagnet heterostructure. We show that the magnetoelastic interaction between the spins and the phonons leads to non-local spin transfer between the magnets. This transfer is mediated by a local phonon spin current and accompanied by a phonon spin accumulation. The spin conductance depends nontrivially on the system size, and decays over centimeter lengthscales for realistic material parameters, far exceeding the decay lengths of magnonic spin currents.

MA 46.2 Thu 9:45 HSZ 403

Compensating the planar Hall effect for better transport measurements — •Tobias Kosub, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany

The planar Hall effect (PHE) can lead to transverse voltage in transport measurements, whenever the studied film has anisotropic conductivity, even when the material conductivity tensor has zero off-diagonal components. Therefore, the PHE presents a complication for measurements of actual transverse components of the conductivity tensor, which are typically several order of magnitude smaller than the longitudinal conductivity (e.g. normal, anomalous Hall effects).

We show that compensating the PHE delivers significant benefits for transverse resistance measurements: For spin Hall magnetoresistance, the longitudinal and transverse components can be easily separated providing easy access to the complex spin mixing conductivity [1].

For Hall probe magnetometry in in-plane magnetic field, the PHE is the dominant error term and rejecting it improves readings greatly.

Compensation of the PHE is achieved using the Zero-Offset Hall [2] measurement mode of the Tensormeter device [3].

[1] T. Kosub et al., *Appl. Phys. Lett.* 113, 222409 (2018)
[2] T. Kosub et al., *Phys. Rev. Lett.* 115, 097201 (2015)
[3] More info on: *www.tensormeter.eu*

MA 46.3 Thu 10:00 HSZ 403

Spin Hall magnetoresistance in heterostructures consisting of noncrystalline paramagnetic YIG and Pt — •Michaela Lammel[1], Richard Schlitz[2], Kevin Geishendorf[1], Denys Makarov[3], Tobias Kosub[3], Savio Fabretti[2], Helena Reichlova[2], Rene Huebner[3], Kornelius Nielsch[1], Andy Thomas[1], and Sebastian T.B. Goennenwein[2] — [1]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden) — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research

The spin Hall magnetoresistance (SMR) effect arises from spin-transfer across the interface between a metal with large spin orbit coupling and an (insulating) magnet. While the SMR response of ferrimagnetic and antiferromagnetic insulators has been studied extensively, the SMR of a paramagnetic spin ensemble is not well established. We here experimentally investigate the magnetoresistance of sputtered yttrium iron garnet/platinum thin film heterostructures[1]. Although we find no evidence for crystalline order or spontaneous magnetization in the yttrium iron garnet layer, we observe a clear magnetoresistive response with a dependence on the magnetic field orientation characteristic for the SMR. We propose two models for the origin of the SMR response in paramagnetic insulator/platinum bilayers and critically compare them to our experimental data.

[1] Lammel et al., Appl. Phys. Lett. **114**, 252402 (2019)

MA 46.4 Thu 10:15 HSZ 403

Spin Hall magnetoresistance in ferromagnet/ Pt heterostructures with 4f moments — •Kevin Geishendorf[1], Richard Schlitz[2], Michaela Lammel[1], Dhavala Suri[3], Jagadeesh Moodera[3,4], Kornelius Nielsch[1], Sebastian T.B. Goennenwein[2], and Andy Thomas[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden — [2]Institut für Festkörper- und Materialphysik , Technische Universität Dresden — [3]Francis Bitter Magnet Laboratory and Plasma Science and Fusion Center, MIT — [4]Department of Physics, MIT

The spin Hall magnetoresistance (SMR) is a powerful tool to investigate a variety of magnetic systems. Previous experiments mainly focused on materials with d moments. d orbitals are usually the outermost magnetic electron shells and thus can overlap with the electron shells of neighbouring ions or atoms resulting in strong interactions. However, the interactions are considered to be weaker in magnetic materials with $4f$ moments due to the strong localization and screening of the $4f$ electrons. We measure the magnetoresistive response (MR) in GdN/Pt and EuS/Pt heterostructures to investigate the coupling between $4f$ moments and a spin accumulation. The GdN/Pt heterostructure exhibits a clear MR with a symmetry characteristic for SMR. In contrast, although having a similar magnetic response the EuS/Pt heterostructure exhibits a much smaller MR. We discuss the possible origin of the MR in both heterostructures in view of the presences or absence of d electron levels near the Fermi energy.

MA 46.5 Thu 10:30 HSZ 403

Large spin Hall magnetoresistance in antiferromagnetic α-Fe_2O_3/Pt heterostructures — Johanna Fischer[1], Matthias Althammer[1], Nynke Vlietstra[1], Hans Huebl[1], Sebastian T. B. Goennenwein[2], Rudolf Gross[1], Stephan Geprägs[1], and •Matthias Opel[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062 Dresden, Germany

We investigate the spin Hall magnetoresistance (SMR) at room temperature in thin film heterostructures of antiferromagnetic, insulating, (0001)-oriented α-Fe_2O_3 (hematite) and Pt. We measure their longitudinal and transverse resistivities while rotating an applied magnetic field of up to 17 T in three orthogonal planes. For out-of-plane magnetotransport measurements, we find indications for a multidomain antiferromagnetic configuration whenever the field is aligned along the film normal [1]. For in-plane field rotations, we clearly observe a sinusoidal resistivity oscillation characteristic for the SMR due to a coherent rotation of the Néel vector [1]. The maximum SMR amplitude of 0.25% is, surprisingly, twice as high as for prototypical ferrimagnetic $Y_3Fe_5O_{12}$/Pt heterostructures [1]. The SMR effect saturates at much smaller magnetic fields as in comparable antiferromagnets, making the α-Fe_2O_3/Pt system particularly interesting for room-temperature antiferromagnetic spintronic applications.

[1] J. Fischer *et al.*, arXiv:1907.13393, *submitted to* Phys. Rev. Appl.

MA 46.6 Thu 10:45 HSZ 403

Injection, transport, detection, and modulation of magnon spin currents in magnetic insulators — •Saül Vélez[1,3], Jialiang Gao[1], Juan Manuel Gomez-Perez[2], Charles-Henri Lambert[1], Luis E. Hueso[2], Morgan Trassin[1], Manfred Fiebig[1], Felix Casanova[2], and Pietro Gambardella[1] — [1]ETH Zürich — [2]CIC nanoGUNE — [3]saul.velez@mat.ethz.ch

Recent demonstration of efficient transport and manipulation of spin information by magnon currents has opened exciting prospects for processing information in devices. Magnon currents can be excited in magnetic insulators by applying charge currents in an adjacent metal layer. Here, by implementing a non-local device scheme, we study the magnon diffusion length (MDL) for electrically and thermally excited magnon currents in Y3Fe5O12 (YIG) and Tm3Fe5O12 (TmIG). In contrast to earlier reports, our temperature and thickness-dependence studies reveal that the MDL depends on the way the magnon currents are generated, evidencing that magnons of different energies are excited (sub-thermal and thermal for electrically- and thermally-driven magnon currents, respectively). Moreover, we demonstrate that the MDL of thermally induced magnons in YIG is the same regardless of the film thickness and growth conditions. We also evaluate the MDL of TmIG and find to be shorter (~300nm) and more susceptible to external fields than it is for YIG, which we attribute to the larger Gilbert damping of TmIG. Finally, by employing a third gate electrode, we demonstrate a current-driven spin-orbit torque modulation of the magnon conductivity in nanometre-thick TmIG films.

MA 46.7 Thu 11:00 HSZ 403

Non-local magnetoresistance in antiferromagnetic insulator/Pt heterostructures — •Richard Schlitz[1], Tobias Kosub[2], Artur Erbe[2], Denys Makarov[2], and Sebastian T. B. Goennenwein[1] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

Non-local magnon mediated magnetoresistance allows to study the transport properties of pure spin currents in ferromagnetic and antiferromagnetic insulators interfaced with a heavy metal like platinum [1, 2]. Recent results suggest that even spin superfluidity can be present in such bilayers, and that it can be detected via the non-local magnetoresistance [3].

In this work, we discuss the thermally driven local and non-local magnetoresistance experimentally observed in antiferromagnetic insulator / Pt heterostructures. We observe the characteristic fingerprint of non-local transport via angle-resolved measurements of the non-local signal. Additionally, we address the impact of contact separation and magnetic field magnitude and critically compare our data to the results presented previously.

[1] L. J. Cornelissen *et al.*. Nature Physics **11**, 1022-1026 (2015)
[2] R. Lebrun *et al.*. Nature **561**, 222-225 (2018)
[3] W. Yuan *et al.*. Science Advances **4**, eaat1097 (2018)

15 min. break.

MA 46.8 Thu 11:30 HSZ 403

Anomalous spin Hall angle in a metallic ferromagnet determined by a multiterminal spin injection/detection device — •T. Wimmer[1,2], B. Coester[1], S. Geprägs[1], R. Gross[1,2,3,4], S. T. B. Goennenwein[5], H. Huebl[1,2,3,4], and M. Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), München, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 München — [5]Institut für Festkörper- und Materialphysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

The spin Hall effect and its characterizing parameter, the spin Hall angle, is crucial for spin to charge conversion processes in spintronics applications. Here, we report on the determination of the anomalous spin Hall angle in the ferromagnetic metal alloy cobalt-iron ($Co_{25}Fe_{75}$, CoFe). This is accomplished by measuring the spin injection/detection efficiency in a multiterminal device with nanowires of platinum (Pt) and CoFe deposited onto the magnetic insulator yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG). Applying a spin-resistor model to our spin transport data, we determine the transport properties of YIG and the anomalous spin Hall angle of CoFe as a function of its spin diffusion length in a single device. Our experiments reveal a negative anomalous spin Hall angle of the ferromagnetic metal CoFe, but a vanishing ordinary spin Hall angle. Financial support by the DFG is gratefully acknowledged.

MA 46.9 Thu 11:45 HSZ 403

Stoner instability investigated by XRMR and XMCD — •Dominik Graulich[1], Jan Krieft[1], Anastasiia Moskaltsova[1], Tobias Peters[1], Johannes Demir[1], Jan Schmalhorst[1], Jose R. Linares Mardegan[2], Sonia Francoual[2], Padraic Shafer[3], Christoph Klewe[3], and Timo Kuschel[1] — [1]Center for Spineletronic Materials and Devices, Bielefeld University, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]Advanced Light Source, LBNL, Berkeley, USA

X-ray resonant magnetic reflectivity (XRMR), in combination with x-ray magnetic circular dichroism, is a very sensitive technique to detect the proximity-induced spin polarization in heterostructures of heavy metals (HMs) in contact to ferromagnetic (FM) materials. This magnetic proximity effect (MPE), caused by the closeness of the HM to the FM instability within the Stoner description, was extensively studied for Pt within the hard x-ray range. Here, a linear dependence between the strength of the MPE, up to 0.7 μ_B per Pt atom, and the magnetic moment of the FM material, as well as a typical effective magnetic Pt thickness of around 1.2 nm were found. With the expansion of the XRMR analysis into the tender and soft x-ray range, the strength and magnetic depth profiles of further materials close to the FM instability (as, e.g., Pd, V, ...) have been investigated at the beamlines P09 (DESY) and 4.0.2 (ALS). This knowledge is crucial for the application of these materials in spintronic devices, where spin transport effects can be altered due to the additional magnetization of the nominal paramagnetic HM layer.

MA 46.10 Thu 12:00 HSZ 403

Asymmetric modification of the magnetic proximity effect in Pt/Co/Pt trilayers — •Ankan Mukhopadhyay[1], Sarathlal Koyiloth Vayalil[1], Dominik Graulich[2], Imran Ahamed[3], Sonia Francoual[4], Arti Kashyap[3], Timo Kuschel[2], and Anil Kumar P S[1] — [1]Indian Institute of Science, Bangalore, India — [2]Center for Spinelectronic Materials and Devices, Bielefeld University, Germany — [3]Indian Institute of Technology, Mandi, India — [4]Deutsches Elektronen-Synchrotron, Hamburg, Germany

Interfacial spin-orbit coupling in ferromagnet/nonmagnet (FM/NM) systems promotes remarkable spin-related phenomena and interactions which simultaneously provide the electrical manipulation of the magnetization to control magnetization switching by current-driven domain wall motion. The phenomenon of a nominally paramagnetic material getting spin-polarized in presence of an adjacent FM material by the exchange interaction, is known as magnetic proximity effect (MPE). The MPE in top and bottom Pt layers induced by Co in Ta/Pt/Co/Pt and Ta/Pt/Co/Cu/Pt multilayers has been studied by interface sensitive, element specific x-ray resonant magnetic reflectivity at the Pt L_3 absorption edge with an in-plane magnetic field. It has been observed that the induced magnetic moment in the bottom Pt layer decreases with the increase of the Ta buffer layer thickness in Ta/Pt/Co/Pt[1], while it decreases in the top Pt layer in Ta/Pt/Co/Cu/Pt due to the increase of the Cu spacer layer.

[1]A. Mukhopadhyay *et al.*, arXiv:1911.12187

MA 46.11 Thu 12:15 HSZ 403

Spin currents in collinear and non-collinear antiferromagnets — •Jakub Železný — Institute of Physics of the Czech Academy of Sciences, Prague 6, Czech Republic

Spin currents are one of the key concepts of spintronics. In the past, two types of spin currents have been predominantly discussed and utilized: the spin-polarized current in ferromagnetic materials and the spin Hall effect. In recent years it has been discovered that the phenomenology of spin currents is much richer than previously thought, and that more types of spin currents can occur. We have shown that the spin-polarized current can also exist in some antiferromagnetic materials and that a new type of spin Hall effect exists, which has origin in the magnetic order, and occurs in ferromagnetic and some antiferromagnetic materials [1]. This effect is now referred to as the magnetic spin Hall effect and has been recently experimentally demonstrated in non-collinear antiferromagnet Mn3Sn [2]. Furthermore, we have shown that the conventional spin Hall effect can exist in some non-collinear magnetic systems even in absence of the relativistic spin-orbit interaction [3]. Here we review the various types of spin currents that can occur in magnetic systems and give general conditions for their existence as well as a symmetry classification. In addition, we present calculations of these novel spin currents in various collinear and non-collinear antiferromagnets.

[1] J. Železný et al.: Phys. Rev. Lett. 119, 187204 (2017) [2] M. Kimata et al., Nature 565, 627 (2019) [3] Y. Zhang et al: New J. Phys. 20, 073028 (2018)

MA 46.12 Thu 12:30 HSZ 403

Crystal Hall effects from antiferromagnetism — •Libor Šmejkal[1,2], Tomáš Jungwirth[2,3], and Jairo Sinova[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnická 10, 162 00 Praha 6 Czech Republic — [3]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom

Antiferromagnetic order is commonly pictured as magnetization projection arrows at the atomic positions in crystals. Here we show that the symmetry analysis arising from this picture is incomplete, and we need to consider the full ground-state magnetization density. We show that this magnetization density in magnets with low symmetry Wyckoff positions and low magnetic symmetry can generate large spontaneous Hall effect [1]. This mechanism revealed strong Hall conductivity from perfectly compensated collinear antiferromagnetism in a large class of spintronics promising materials previously anticipated to be prohibited from spontaneous Hall effect. We analyse the topological origin of the crystal Hall conductivity contributions in centrosymmetric RuO2 and chiral crystal CoNb3S6. Finally, we will discuss possible experimental discoveries of the effect and impact of the mechanism on other spintronics phenomena[2]. [1] L. Šmejkal, R. González-Hernández, T. Jungwirth, and J. Sinova, arXiv:1901.00445v1 (2019) [2]L. Šmejkal, Y. Mokrousov, B. Yan, and A. H. MacDonald, Nature Physics, 14, 242 (2018)

MA 46.13 Thu 12:45 HSZ 403

Structural, electrical transport and magnetization dynamic properties of epitaxial Mn3Ir/Ni3Fe heterostructures — •Sri Sai Phani Kanth Arekapudi[1], Fabian Ganss[1], Antje Oelschlägel[3], Anna Semisalova[3], Sven Stienen[3], Kilian Lenz[3], Jürgen Lindner[1], Manfred Albrecht[2], and Olav Hellwig[1,3] — [1]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [2]Institute of Physics, University of Augsburg, Universitätsstraße 1,86159 Augsburg, Germany — [3]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany

In spin-orbitronic devices, non-collinear antiferromagnets (AFM) such as Mn3Ir are used as active spin current injection electrodes for an efficient charge to spin current conversion [1]. Here we present a detailed procedure for the preparation of high-quality epitaxial thin films of cubic Mn3Ir (AFM) and Ni3Fe (FM) heterostructures. A comprehensive study of the crystal structure is performed using X-ray diffraction and high-resolution TEM imaging. Dynamic magnetic excitation studies of Mn3Ir/Ni3Fe heterostructures confirm the strong dependence of Gilbert damping and interfacial spin structure on the antiferromagnetic film thickness. Furthermore, we also reveal the role of AFM/FM interface spin-current transparency, which is pivotal for the spin Hall effect (SHE). [1] W. Zhang et al., Giant facet-dependent spin-orbit torque and spin Hall conductivity in the triangular antiferromagnet IrMn3. Sci. Adv. 2, e1600759 (2016).

MA 47: Skyrmions IV (joint session MA/TT)

Time: Thursday 9:30–11:15 Location: POT 6

MA 47.1 Thu 9:30 POT 6

Exploring the tunability of skyrmion lifetimes in 3D materials — •Markus Hoffmann, Gideon P. Müller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Chiral magnetic skyrmions are of great scientific interests but also of potential relevance in information technology, data storage, processing, and neuromorphic computing. To compete with existing technology, those skyrmions have to fulfill stringent requirements: Long lifetimes at room temperature at small sizes. Therefore, a significant effort of the magnetism community lies on the analysis of the stability of such small skyrmions. One commonly used approach is the calculation of energy barriers by performing LLG and GNEB simulations as well as the determination of the lifetime prefactor by HTST [1]. Up to now, those were mainly performed for skyrmions in 2D systems, *i.e.* atomic layers. For technological applications, however, the third dimension can play a significant role. Particularly magnetic multilayers as well as exchange biased materials are in the focus of interest for technologically relevant materials. Yet, little is known about the stability of skyrmions in such materials. We therefore performed lifetime calculations within our Spirit code [2] and investigated the tunability of skyrmion lifetimes by effects such as exchange bias or interlayer coupling.

We acknowledge funding from the DARPA TEE program through grant MIPR (#HR0011831554) from DOI.

[1] P. F. Bessarab *et al.*, Phys. Rev. B **85** (18), 184409 (2012)

[2] Spirit spin simulation framework, spirit-code.github.io

MA 47.2 Thu 9:45 POT 6

Electrical Transport in FIB microstructures of $Mn_{1.4}PtSn$ — •M. Winter[1,2], S. Hamann[1,3], J. Gayles[3], P. Vir[3], M. Uhlarz[1], M. König[3], C. Felser[3], J. Wosnitza[1,2], and T. Helm[1,3] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

$Mn_{1.4}PtSn$ is a half-Heusler compound with tetragonal crystal structure. Only recently, Lorentz transmission electron microscopy measurements have shown that, so-called antiskyrmion phases can be stabilized by applying a magnetic field to the material. Futhermore, it is known that non-trivial magnetic structures such as skyrmions cause a topological contribution to the Hall effect. Therefore, investigations of the electrical transport properties of the material are highly desirable. By using a focused ion beam, we are able to produce samples with submicron feature size, close to the coherence length of the occurring magnetic structures, while maintaining the high quality of a single crystal. This opens the possibility to measure influences of the sample geometry, such as local effects and finite-size effects, on the topological Hall effect caused by the antiskyrmions in $Mn_{1.4}PtSn$.

MA 47.3 Thu 10:00 POT 6

Towards the 3D quantification of Skyrmions in thin helimagnets — •Sebastian Schneider[1,2], Daniel Wolf[1], Matthew J. Stolt[3], Song Jin[3], Marcus Schmidt[4], Darius Pohl[2,1], Bernd Rellinghaus[2,1], Bernd Büchner[1], Sebastian T. B. Goennenwein[2], Kornelius Nielsch[1], and Axel Lubk[1] — [1]IFW Dresden, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]University of Wisconsin-Madison, Madison, USA — [4]MPI CPfS, Dresden, Germany

The anticipated application of skyrmions as information carriers in magnetic thin film devices depends crucially on the stability and mobility of these solitons. Within the scope of this work the microscopic magnetic structure of skyrmions, which determines their transport properties, is investigated by means of magnetic measurement methods in transmission electron microscopy. To study the three-dimensional spin texture of Bloch skyrmions in thin helimagnets of FeGe and $Fe_{0.95}Co_{0.05}Ge$ focal series electron holography and off-axis electron holography is employed to determine quantitative maps of the projected in-plane magnetic induction. Although these magnetic induction maps carry the clear signature of Bloch skyrmions, their magnitude is much smaller than the values expected for homogeneous skyrmions extending throughout the thickness of the film. Such a reduction can amongst others be caused by a modulation of the underlying spin textures along the out-of-plane z direction. To further analyse these modulations first electron holographic tomography experiments on Bloch skyrmions in an FeGe needle are performed.

MA 47.4 Thu 10:15 POT 6

Skyrmions for reservoir computing — •Karin Everschor-Sitte — Institute of Physics, Johannes Gutenberg-University Mainz

The topological properties of magnetic skyrmions, their inherent compact particle-like nature and their complex and nonlinear dynamics make skyrmions interesting for spintronics applications and in particular unconventional computing schemes. [1] In this talk I will address the potential of magnetic skyrmions for reservoir computing, i.e. a computational scheme which allows to drastically simplify spatial-temporal recognition tasks. We have shown that random skyrmion fabrics provide a suitable physical implementation of the reservoir [2,3] and allow to classify patterns via their complex resistance responses either by tracing the signal over time or by a single spatially resolved measurement. [4]

[1] G. Finocchio et al., arXiv:1907.04601 [2] D. Prychynenko et al., Phys. Rev. Appl. **9**, 014034 (2018) [3] G. Bourianoff et al., AIP Adv. **8**, 055602 (2018) [4] D. Pinna et al., arXiv:1811.12623

MA 47.5 Thu 10:30 POT 6

Skyrmion size and shape within continuous magnetization model and atomistic spin model — •Anastasiia S. Varentsova[1,2] and Pavel F. Bessarab[1,2,3] — [1]ITMO University, St. Petersburg, Russia — [2]University of Iceland, Reykjavík, Iceland — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

We explore the relationship between two approaches to the description of skyrmions in magnetic materials. One of the approaches involves characterization of magnetic states by a continuous magnetization field. Within the other approach, magnetic structures are represented by magnetic moments localized on vertices of a discrete lattice. By tracing contours of constant skyrmion size in the material parameter space, we demonstrate that the continuous magnetization model and the lattice model agree quite well for large skyrmions with smooth profiles, but predict different results for small skyrmions and skyrmions with bubble-like shape. We propose to link the two models by a material parameter transformation that does not rely on the assumption of small spatial variation of the magnetic structure on the scale of the lattice constant. As a result, good agreement between the continuous magnetization theory and the lattice model can be obtained for the whole skyrmion sector of the magnetic phase diagram.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138), the Icelandic Reseach Fund (Grant No. 184949-052) and Alexander von Humboldt Foundation.

MA 47.6 Thu 10:45 POT 6

Topologically Non-trivial Magnetic and Polar Patterns in Lacunar Spinels — •Markus Preissinger[1], Hans-albrecht Krug von Nidda[1], Axel Lubk[2], Sándor Bordács[3], Hiroshi Nakamura[4], Vladimir Tsurkan[1], and István Kézsmárki[1] — [1]Experimentalphysik V, Universität Augsburg — [2]Advanced Methods of Electron Microscopy, IFW Dresden — [3]Magneto-Optical Spectroscopy Group, Budapest University of Technology and Economics — [4]Department of Materials Science and Engineering, Kyoto University

The lacunar spinels $Ga(V/Mo)_4(S/Se)_8$ have been the first candidates, where the emergence of Néel-type skyrmions, induced by Dzyaloshinsky-Moriya interaction, has been reported. This group of materials undergo a Jahn-Teller transition at about 40 K losing inversion symmetry in the process. Upon further cooling the system enters a magnetically ordered state. The ground state is a cycloidal phase, while critical fields strongly depend on the direction in which the magnetic field is applied [1][2]. In an attempt to image skyrmions with Lorentz-transmission-electron microscopy (LTEM), we succeeded to find the cycloidal ground state in thin lamellae of $GaV_4(S/Se)_8$ (<100nm) at a hugely increased temperature simultaneously to the Jahn-Teller distortion. In thin lamellae of $GaMo_4S_8$ no magnetic texture but a regular pattern of polarised structural domains has been found, presumably indicating polar skyrmions.

[1] I. Kézsmárki, NMAT 2015, Vol14, pp 1116-1122;
[2] S. Bordács Sci. Rep. 2017, Vol 7, Article number 7548

MA 47.7 Thu 11:00 POT 6

Hopfions in magnetic crystals — Filipp N. Rybakov[1], •Nikolai S. Kiselev[2], Aleksandr B. Borisov[3], Lukas Döring[4], Christof Melcher[4], and Stefan Blügel[2] — [1]Department of Physics, KTH-Royal Institute of Technology, SE-10691 Stockholm, Sweden — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [3]Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Ekaterinburg 620990, Russia — [4]Department of Mathematics I & JARA FIT, RWTH Aachen University, 52056 Aachen, Germany

Hopfions are three-dimensional topological solitons, which can be thought of as skyrmion tubes with closed ends. In the pioneering work of Bogolyubsky [1], it was shown that in the micromagnetic model with higher-order derivatives of the order parameter, the hopfions might appear as statically stable solutions. Here we show that the general form of such a micromagnetic functional can be derived from classical spin-lattice Hamiltonians with competing Heisenberg exchange interactions. We present this advanced micromagnetic functional derived for lattices of cubic symmetry and provide a criterion for the existence of hopfions in the systems described by such a functional [2]. Following our approach, similar functionals can be derived for materials of any crystal symmetry. We discuss a variety of hopfion solutions, their static and dynamic properties, and provide concrete guidance for the search of magnetic crystals that allow the existence of hopfions.

[1] I. L. Bogolubsky, Phys. Lett. A **126**, 511 (1988).
[2] F. N. Rybakov, *et al.*, arXiv:1904.00250.

MA 48: Ultrafast Electron Dynamics III (joint session O/MA)

Time: Thursday 10:30–12:45 Location: WIL B321

MA 48.1 Thu 10:30 WIL B321

THz-induced oscillations of the band structures in the topological insulator Bi_2Te_3 — •Suguru Ito[1], Johannes Reimann[1], Stefan Schlauderer[2], Christoph Schmid[2], Fabian Langer[2], Sebastian Baierl[2], Josef Freudenstein[2], Manuel Meierhofer[2], Konstantin Kokh[3], Oleg Tereshchenko[3], Akio Kimura[4], Christoph Lange[2], Jens Güdde[1], Rupert Huber[2], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps-Universität Marburg, Germany — [2]Fakultät für Physik, Universität Regensburg, Germany — [3]Novosibirsk State University, Russia — [4]Graduate School of Science, Hiroshima University, Japan

Time- and angle-resolved photoemission spectroscopy (time-resolved ARPES) is a powerful tool to map ultrafast dynamics occurring in electronic band structures. New opportunities arise in combination with THz excitation. As demonstrated recently for the topological surface bands of Bi_2Te_3, THz-ARPES is capable of mapping the dynamics of electrical currents in k-space with sub-cycle time resolution [1]. Here, we show that the THz light field also induces oscillations of the electronic bands on a time scale longer than the duration of the field transient. Frequency analysis implies the origin in atomic displacements but reveals the existence of oscillation modes that cannot be attributed to phonons in bulk Bi_2Te_3. Our results suggest another perspective of THz-ARPES, the capability to track band-structure en-

gineering by light. We will discuss the experiment and compare with electronic structure calculations.
[1] J. Reimann *et al.* Nature **562**, 396 (2018).

MA 48.2 Thu 10:45 WIL B321

Spin-, time- and angle-resolved photoemission spectroscopy on WTe2 — •Mauro Fanciulli[1,2], Jakub Schusser[1,3], Christine Richter[1,2], Cephise Cacho[4], David Bresteau[2], Thierry Ruchon[2], Jan Minár[3], and Karol Hricovini[1,2] — [1]LPMS, CY Cergy Paris Université, Cergy, FR — [2]LIDYL, CEA Saclay, Gif-sur-Yvette, FR — [3]NTC, University of West Bohemia, Pilsen, CZ — [4]Diamond Light Source, Didcot, UK

We combined a spin-resolved photoemission spectrometer with a high-harmonic generation (HHG) laser source in order to perform spin-, time- and angle-resolved photoemission spectroscopy (STARPES) experiments on the transition metal dichalcogenide bulk WTe2, a possible Weyl type-II semimetal. Measurements at different femtosecond pump-probe delays and comparison with spin-resolved one-step photoemission calculations provide insight into the spin polarization of electrons above the Fermi level in the region where Weyl points of WTe2 are expected. We observe a spin accumulation above the Weyl points region, that is consistent with a spin-selective bottleneck effect due to the presence of spin polarized cone-like electronic structure. Our results support the feasibility of STARPES with HHG, which despite being experimentally challenging provides a unique way to study spin dynamics in photoemission.

MA 48.3 Thu 11:00 WIL B321

Mode-resolved reciprocal space mapping of electron-phonon interaction in the Weyl semimetal candidate *Td*-WTe$_2$ — •Petra Hein[1], Stephan Jauernik[1], Hermann Erk[1], Lexian Yang[2], Yanpeng Qi[3], Yan Sun[4], Claudia Felser[4], and Michael Bauer[1] — [1]Institute of Experimental and Applied Physics, CAU Kiel, Germany — [2]State Key Laboratory of Low Dimensional Quantum Physics, Tsinghua University, China — [3]School of Physical Science and Technology, ShanghaiTech University, China — [4]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The selective excitation of coherent phonons provides unique capabilities to control fundamental properties of quantum materials on ultrafast time scales. For instance, in the presence of strong electron-phonon coupling, the electronic band structure can become substantially modulated. Recently, it was predicted that by this means even topologically protected states of matter can be manipulated: Pairs of Weyl points in *Td*-WTe$_2$ are expected to annihilate as an interlayer shear mode drives the material towards a centrosymmetric phase [1].
Here, time- and angle-resolved photoelectron spectroscopy is used to monitor the changes in the electronic structure of *Td*-WTe$_2$ upon absorption of 1.5 eV femtosecond laser pulses. We provide direct experimental evidence that the coherent excitation of the shear mode acts on the electronic states near the Weyl points. By comparison with higher-frequency coherent phonon modes, we finally prove the shear mode-selectivity of the observed changes in the electronic structure.
[1] E. J. Sie *et al.*, Nature **565**, 61-66 (2019).

MA 48.4 Thu 11:15 WIL B321

Ultrafast Light-Induced Lifshitz Transition — •Samuel Beaulieu[1], Shuo Dong[1], Nicolas Tancogne-Dejean[2], Maciej Dendzik[1], Julian Maklar[1], Tomasso Pincelli[1], R. Patrick Xian[1], Martin Wolf[1], Angel Rubio[2,3], Michael A. Sentef[2], Laurenz Rettig[1], and Ralph Ernstorfer[1] — [1]Fritz-Haber- Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics, of Matter and Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth Avenue, New York NY 10010

Fermi surface is at the heart of our understanding of the properties of metals and strongly correlated many-body systems. An abrupt change in the Fermi surface topology, also called Lifshitz transition, can lead to the emergence of fascinating phenomena like colossal magnetoresistance and superconductivity. While Lifshitz transitions have been demonstrated for a broad range of materials and using different types of static external perturbations like strain, doping, pressure and temperature, a nonequilibrium route toward ultrafast and transient switching of the Fermi surface topology has not been demonstrated yet. Using time-resolved multidimensional photoemission spectroscopy combined with TDDFT+U simulations, we demonstrate a scheme based on ultrafast laser-driven band renormalization that drives a Lifshitz transition in the topological type-II Weyl semimetal $T_d - MoTe_2$, due to transient modification of effective electron-electron interactions.

MA 48.5 Thu 11:30 WIL B321

Time-resolved Momentum Microscopy of an Ultrafast Charge-Density-Wave-to-Metal Transition — •Julian Maklar[1], Shuo Dong[1], Samuel Beaulieu[1], Tommaso Pincelli[1], Maciej Dendzik[1], Philip Walmsley[2], Ian Fisher[2], Ralph Ernstorfer[1], Martin Wolf[1], and Laurenz Rettig[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Deutschland — [2]GLAM, Department of Applied Physics, Stanford, California, USA

Complex solids exhibit a multitude of competing and intertwined orders. A promising approach to disentangle relevant interactions and energy scales is by perturbation via ultrafast photoexcitation. However, this requires tracking of the electronic structure upon photoexcitation across a large energy and momentum range with femtosecond (fs) time-resolution in order to capture all relevant electronic processes.

Here, we investigate the evolution of the electronic band structure of the prototypical 2D charge-density-wave (CDW) compound $TbTe_3$ after photo-excitation. We utilize a new method, i.e. XUV time-resolved momentum microscopy, to simultaneously map a large energy- and momentum region with 40 fs temporal resolution. This allows us to identify collective excitations of the CDW as well as a strong coupling to a distinct phonon mode across multiple Brillouin zones.

MA 48.6 Thu 11:45 WIL B321

Heavy fermion dynamics in semimetallic and insulating phases — •chul-hee min[1], michael heber[2], simon müller[3], lukas wenthaus[2], steffen palutke[2], dmytro kutnyakhov[2], federico pressacco[4], lenart dudy[5], mathieu silly[5], celso fornari[3], kiana baumgärtner[3], hendrik bentmann[3], woojae choi[6], yong seung kwon[6], markus scholz[7], friedrich reinert[3], wilfried wurth[2,4], and kai rossnagel[1,2] — [1]IEAP, CAU Kiel, Germany — [2]DESY, Hamburg, Germany — [3]EP7 and ct.qmat, University of Würzburg, Germany — [4]Department of Physics, University of Hamburg, Germany — [5]Synchrotron-SOLEIL, Saint-Aubin, France — [6]Department of Emerging Materials Science, DGIST, Republic of Korea — [7]European XFEL GmbH, Schenefeld, Germany

Due to time–energy correlation, heavy fermion systems with hard-to-detect meV energy scales are expected to show relatively slow dynamics on ps time scales, which are relatively easy to measure. Using the free-electron laser FLASH, we have performed time-resolved pump-probe photoemission spectroscopy of mixed valent $TmSe_{1-x}Te_x$. The system is composed of two magnetic $4f^{12}$ and $4f^{13}$ configurations in the ground state and can be tuned from semimetallic to insulating behavior via the Te concentration x without destroying the periodicity of the Tm ions. Here, we present and discuss the transient dynamics of the $4f$ states near E_F showing a remarkably strong dependence on x.

MA 48.7 Thu 12:00 WIL B321

Polarisation effects in real space and real time in Xe-Cs solvatomers on Cu(111) — John Thomas[1], •Cord Bertram[1,2], Ping Zhou[1], Manuel Ligges[1], Karina Morgenstern[2], and Uwe Bovensiepen[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Lehrstuhl für Physikalische Chemie I, Ruhr-Universität Bochum, 44780 Bochum, Germany

For understanding solvation under spatial constraints, morphology and ultrafast electron dynamics of solvent-solute complexes on surfaces are essential. In this contribution, we present the influence of the rare-gas, non-polar solvent xenon on the electronic structure of Cs/Cu(111) investigated by Scanning Tunneling Microscopy (STM) and Two-Photon-Photoelectron Spectroscopy (2PPE). After adsorption of xenon onto Cs precovered Cu(111), Cs agglomerates in xenon islands to a distance within the islands that is limited by Coulomb repulsion. The cesium antibonding resonance attributed to the Cs 6s orbital shifts up in energy with increasing Xe coverage and the lifetime of the antibonding resonance is increased from 15 fs to 81 fs. We interpret these results as an enhanced localization of the antibonding resonance and a decoupling of Cs from Cu(111), mediated by the polarization response of Xe in the close vicinity of Cs. Such effects will be discussed in the context of solvation and de-solvation of Cs-Xe complexes on Cu(111). We acknowledge that this contribution is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2033 - Projektnummer 390677874.

MA 48.8 Thu 12:15 WIL B321

Investigation of coherent phonons at the interface of GaP/Si(001) heterostructures — •Steven Youngkin[1], Gerson Mette[1], Kunie Ishioka[2], Wolfgang Stolz[1], and Ulrich Höfer[1] — [1]Fachbereich Physik, Philipps Universität Marburg, Germany — [2]National Institute for Material Science, Tsukuba, Japan

Breaking of the bulk lattice atomic ordering by a surface leads to a plethora of novel and interesting physical phenomena such as new vibronic states, commonly known as surface phonon modes. However, very little is known about the vibronic states that arise at an interface of two solids.

Here, we use coherent phonon spectroscopy to study the interface vibronic system of GaP/Si(001) heterostructures, which represent a structurally well characterized model system of a polar/non-polar inorganic semiconductor interface. By measuring the transient reflectivity change of the probe beam at various pump photon energies, we can monitor the energy dependence of the coherent excitation of phonon modes with a resolution limited by the ultrashort laser pulses. Our studies reveal the existence of a low-frequency phonon mode with a frequency of 2 THz. This vibrational mode is absent in both bulk systems and is therefore assigned to originate from the buried interface between GaP and Si.

MA 48.9 Thu 12:30 WIL B321

Three time-resolved photoelectron spectroscopies in one setup - time-of-flight momentum microscope at free electron laser. — •D. Kutnyakhov[1], R.P. Xian[2], M. Dendzik[2], M. Heber[1], F. Pressacco[3], S.Y. Agustsson[4], L. Wenthaus[1], H. Meyer[3], S. Gieschen[3], K. Bühlman[5], S. Däster[5], R. Gort[5], D. Curcio[6], K. Volckaert[6], M. Bianchi[6], Ch. Sanders[6], J.A. Miwa[6], S. Ulstrup[6], A. Oelsner[7], C. Tusche[8,9], Y.-J. Chen[8,9], D. Vasilyev[4], K. Medjanik[4], G. Brenner[1], S. Dziarzhytski[1], S. Dong[2], J. Hauer[2], L. Rettig[2], J. Demsar[4], K. Rossnagel[1,10], H.-J. Elmers[4], Ph. Hofmann[6], R. Ernstorfer[2], G. Schönhense[4], Y. Acremann[5], and W. Wurth[1,3] — [1]DESY, Hamburg — [2]FHI Berlin — [3]CFEL, Univ. Hamburg — [4]Univ. Mainz — [5]ETH Zürich — [6]Univ. Aarhus — [7]Surface Concept GmbH, Mainz — [8]FZ Jülich GmbH — [9]Univ. Duisburg-Essen — [10]IEAP, CAU Kiel

Time-resolved photoemission with ultrafast pump and probe pulses is an emerging technique with wide application potential. Combining valence-band and core-level spectroscopy with photoelectron diffraction in a single efficient photoelectron-detection setup for electronic, chemical and structural analysis requires soft X-ray pulses (width few 10 fs) with some 10 meV spectral resolution. This is feasible at high repetition rate free-electron lasers using parallel imaging with segmented single-shot detectors with increased multi-hit capabilities. We have constructed and optimized a versatile setup commissioned at FLASH/PG2 that combines free-electron-laser capabilities with a multidimensional recording scheme for photoemission studies.

MA 49: Focus Session: Higher-Order Magnetic Interactions – Implications in 2D and 3D Magnetism II

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

Invited Talk MA 49.1 Thu 15:00 HSZ 04

The role of itinerant electrons and higher order magnetic interactions among fluctuating local moments in producing complex magnetic phase diagrams. — Julie Staunton[1], Eduardo Mendive-Tapia[1,2], and •Christopher Patrick[1,3] — [1]University of Warwick, U.K — [2]Max-Planck Institut Fur Eisenforschung GmbH, Germany — [3]University of Oxford, U.K.

When external stimuli or varying temperature alter its magnetic properties a metal's complex electronic fluid with its emergent magnetic 'local moments' transforms. In this context the ab initio Density Functional Theory-based Disordered Local Moment method can successfully locate and characterise magnetic phase transitions and calculate caloric effects. It will be shown how the theory provides a Gibbs free energy function of local moment order parameters with two central objects - local moment correlation functions in the paramagnetic state and local internal magnetic fields as functions of magnetic order. The potentially most stable magnetic phases and dominant interactions between pairs of local moments are identifiable from the first. Higher order correlations extracted from the second produce effective 'multisite' magnetic interactions depending on how the electronic structure evolves with the state and extent of magnetic order. The approach will be illustrated by applications to the magnetic order of the heavy rare earth metals, the tricritical metamagnetism in frustrated antiferromagnets with rich magnetic-strain phase diagrams and associated caloric effects, and finally the exceptional non-hysteretic first order magnetic phase transition in the divalent lanthanide compound Eu2In.

MA 49.2 Thu 15:30 HSZ 04

Origin of the short-period magnetic structure of MnGe from a first-principles high-temperature free energy — •Eduardo Mendive Tapia[1,2], Manuel dos Santos Dias[1], Stefan Blügel[1], and Samir Lounis[1] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Computational Materials Design, Max-Planck Institut für Eisenforschung, 40237 Düsseldorf, Germany

The helimagnetism of B20-type compounds such as MnSi and FeGe is usually understood as a competition between the ferromagnetic exchange interaction and the chiral Dzyaloshinskii-Moriya interaction. The magnetism of MnGe defies this interpretation owing to the short-period of its 3q magnetic structure and distinct B-T magnetic phase diagram [1]. Using a Disordered Local Moment theory implemented in the Korringa-Kohn-Rostoker method [2,3], we construct a first-principles high-temperature free energy for MnGe, which explains the short-period from competing long-range interactions. Our calculations also reproduce experimental volume-dependence of both the period and the Néel transition temperature. The first-principles magnetic phase diagram obtained points to the importance of higher-order magnetic exchange interactions to explain the observed 3q and 4q magnetic structures.—Work funded by the DAAD and EU Horizon 2020 via ERC-consolidator Grant No. 681405–DYNASORE.

[1] Fujishiro *et al.*, Nat. Commun. **10**, 1059 (2019)
[2] Gyorffy *et al.*, J. of Phys. F: Metal Phys. **15**, 1337 (1985)
[3] Jülich KKR codes (https://jukkr.fz-juelich.de)

MA 49.3 Thu 15:45 HSZ 04

Beyond Heisenberg exchange: non-collinear formalism for bcc Fe — •A. Szilva[1], D. Thonig[1], P.F. Bessarab[2,3], Y. O. Kvashnin[1], D. C. M. Rodrigues[1,4], R. Cardias[1,4], M. Pereiro[1], L. Nordström[1], A. Bergman[5,6], A. B. Klautau[4], and O. Eriksson[1,7] — [1]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Science Institute of the University of Iceland, 107 Reykjavik, Iceland — [3]Department of Nanophotonics and Metamaterials, ITMO University, 197101 St. Petersburg, Russia — [4]Faculdade de Física, Universidade Federal do Pará, Belém, 66075-110, Brazil — [5]Maison de la Simulation, USR 3441, CEA-CNRS-INRIA-Université Paris-Sud-Université de Versailles, F-91191 Gif-sur-Yvette, France — [6]INAC-MEM, CEA, F-38000 Grenoble, France — [7]School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden

The orbital resolved LKAG exchange calculations show that an entirely different microscopic mechanisms work in the T2g than in the Eg (and "mixed") orbitals in bcc Fe. Study of interatomic exchange parameters in a non-collinear framework, which parameters can be interpreted as higher order spin terms, too, is in line with these findings: the nearest-neighbor exchange parameters related to the T2g orbitals are essentially Heisenberg-like, ie., they do not depend on the underlying spin-configuration. In contrary, in the Eg and mixed channels strong configuration dependence can be found when one spin is fully rotated in a ferromagnetic background. The presentation is mostly based on the results published on Ref Phys. Rev. B 96 (14), 144413 (2017).

MA 49.4 Thu 16:00 HSZ 04

Short- and long-range toroidal order in nanomagnetic arrays — •Jannis Lehmann[1], Amadé Bortis[1], Naëmi Leo[2,3], Claire Donnelly[2], Peter Derlet[2], Laura J. Heyderman[1,2], and Man-

fred Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Paul Scherrer Institute, Villigen PSI, Switzerland — [3]CIC nanoGUNE, Donostia-San Sebastián, Spain

Ferrotoroidicity, i.e. the collective alignment of uniformly-oriented magnetic whirls that spontaneously form at the unit-cell level, is an elusive type of magnetically-compensated ferroic order. Since compounds displaying ferrotoroidicity are rare and difficult to identify because the access to their compensated magnetic order is experimentally challenging, we here make use of artificial planar nanostructures made from ferromagnetic building blocks as a versatile approach to design and study magnetic frustration or other phenomena. We introduce arrays of stray-field-coupled single-domain- or vortex-state nanomagnets of different geometry that exhibit emergent ferrotoroidic order at mesoscopic length scales. We perform magnetic force microscopy to achieve spatial access to the magnetic configuration and the toroidal domain pattern. By varying the arrangement of building blocks we tune the delicate competition of microscopic couplings between the nanomagnets. We find that this competition influences key observables of ferroic order as e.g. the domain size, the domain-wall configuration and the density of topological defects. We explain our observations by identifying different multipolar pathways to long-range order.

MA 49.5 Thu 16:15 HSZ 04

Competing Non-collinear Magnetic Phases in Osmates Double Perovskites — •Dario Fiore Mosca — University of Vienna & VDSP, Vienna, Austria

The interplay between electron correlation, local symmetry and spin-orbit coupling is among the most challenging aspect of condensed matter physics. These energy scales are simultaneously active in 5d transition metal oxides, which represent a rich playground for discovering new quantum states of matter. In particular, strong relativistic effects can lead to the formation of complex non-collinear magnetic orderings, whose origin cannot be understood within a standard Heisenberg picture. In our work, we study the ground state of the $5d^1$ osmate-based double perovskite Ba_2NaOsO_6 and decipher the driving mechanism that leads to the onset of the observed canted antiferromagntic pattern. The structural, electronic and magnetic properties of Ba_2NaOsO_6 are computed using fully relativistic and magnetically constrained DFT + U. We find that the magnetic energy landscape (in particular the canting angle) depends critically on the cooperative Jahn-Teller distortions and on the strength of the effective electron correlation U-J. In order to acquire additional information on the quantum origin of the canted AFM state we map the first principles total energies onto an extended pseudospin Hamiltonian, and find that dipolar and octupolar terms are the key interactions that drive the stabilization of the noncollinear ground state.

MA 49.6 Thu 16:30 HSZ 04

Hole doped 214-nickelate: A case study of spin dynamics in 3D-DCSS — •Rajesh Dutta[1,3] and Avishek Maity[2,3] — [1]Institut für Kristallographie, RWTH Aachen University — [2]Technical University of Munich, Germany — [3]Heinz Maier-Leibnitz Zentrum, FRM-II, Garching)

Inelastic neutron scattering study on the magnetic excitation in a stripe-ordered Pr2-xSrxNiO4 at 5K reveal that dynamics are manifested by order magnetic incommensurability as result of admixing 1/3-stripe with the checkerboard matrix in NiO2 plane so called discommensurated spin stripe (DCSS). A suggested linear spin-wave model accounting 3D- DCSS with two-fold exchange interactions between Ni2+ spins, provides a good agreement with the measured spin wave dispersion up to 64 meV, notably, to describe a slight symmetric shift of the broadened peak in the energy range of 35 - 45 meV. Our results indicate that DCSS model is essential to consolidate in the LSWT calculation to understand the microscopic effect of doped holes on the spin microstructure.

MA 49.7 Thu 16:45 HSZ 04

Long-range chiral exchange interaction in synthetic antiferromagnets — Dong-Soo Han[1], Kyujoon Lee[1], •Fabian Kammerbauer[1], Myung-Hwa Jung[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Department of Physics, Sogang University, Seoul, Republic of Korea

The exchange interaction underlies all spintronic devices. This interaction has two counterparts * the symmetric and antisymmetric part. The symmetric term governs the ferro- and antiferromagnetism where the antisymmetric which has recently gained interest since it promotes topologically non-trivial chiral spin textures that promise new magnetic devices . So far, the antisymmetric exchange interaction has only been demonstrated in the rather short range limited to a single magnetic layer. Here we report a long-range antisymmetric interlayer exchange interaction in perpendicularly magnetized synthetic antiferromagnets with parallel and antiparallel magnetization alignments [1]. The measured asymmetric hysteresis loops under an in-plane field reveal a unidirectional and chiral nature of this interaction, resulting in canted magnetic structures. We explain our results by considering spin*orbit coupling combined with reduced symmetry in multilayers. Our discovery of a long-range chiral interaction provides an additional handle to engineer magnetic structures and could enable three-dimensional topological structures. [1] D.Han et al., Nature Mater. 18, 905 (2019)

MA 50: Permanent Magnets

Time: Thursday 15:00–17:30 Location: HSZ 101

MA 50.1 Thu 15:00 HSZ 101

High-throughput and data-mining search for rare-earth free permanent magnets — •Alena Vishina[1], Olga Yu. Vekilova[1], Heike C. Herper[1], and Olle Eriksson[1,2] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]School of Science and Technology, Örebro University, Örebro, Sweden

High performance permanent magnets are needed for a large number of applications, such as electric motors, wind mills, and many more. At the same time most high performance magnets contain rare-earth (RE) materials which makes them expensive, while some of the RE elements are rapidly decreasing in availability.

We've applied a high-throughput and data-mining approach to the search of rare-earth free permanent magnets. Going through a large number of known structures from ICSD database, and using a full-potential linear muffin-tin orbital method with relativistic formulation as implemented in the RSPt electron structure code to calculate magnetic anisotropy and Curie temperature, we were looking for the materials with high magnetization > 1 T, uniaxial anisotropy > 1 MJ/m^3, and T_c > 300 K to identify the suitable replacement for rare-earth containing materials.

Starting with the materials containing 3d+5d+1 extra element of the periodic table to test the method, we have found several candidates that have characteristics suitable for a good permanent magnet, such as Pt_2FeCu, Pt_2FeNi, W_2FeB_2, etc (arXiv:1910.00548 [cond-mat.mtrl-sci]).

MA 50.2 Thu 15:15 HSZ 101

Computational design of rare-earth lean hard magnetic phases — •Heike C. Herper[1], Olga Yu. Vekilova[1], Pablo Nieves[2], and Olle Eriksson[1,3] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]T4Innovations, VŠB Technical University of Ostrava, Czech Republic — [3]School of Science and Technology, Örebro University, Sweden

Today nearly all high performance magnets are based on $Nd_2Fe_{14}B$ and the demand for such magnets is increasing. Thus more permanent magnets are needed but the new materials should have a smaller environmental footprint. Fe-rich phases with the $ThMn_{12}$ structure contain less RE than the commercially used compounds.

We performed a systematic ab initio study of $REFe_{12-x}Z_x$ with RE = Nd, Y, Ce, Sm; Z = Ti, V aiming to tune the magnetic performance towards large uniaxial magnetocrystalline anisotropy and high T_C by using a combination of different state of the art first principles methods combined with atomistic simulation methods for temperature dependent properties. Apart from Sm in practice N must be added to e.g. improve the coercive field. Since especially N can alter the orientation of the easy axis it has been included in the study.

Several promising phases could be identified. Here, $YFe_{11.5}Ti_{0.5}N$, and $Nd_{0.5}Y_{0.5}Fe_{11}Ti(N)$, and $SmFe_{11}V$ will be discussed. The last one has been already synthesized showing an good magnetic performance.[J. Alloys and compounds **786**, 969 (2019)]
This work was supported by NOVAMAG (EU686056) and Swedish Foundation for Strategic Research (EM16-0039).

MA 50.3 Thu 15:30 HSZ 101

Computational screening of Fe-Ta magnetic phases — •Sergiu Arapan[1], Pablo Nieves[1], Heike C. Herper[2], and Dominik Legut[1] — [1]IT4Innovations, VŠB - Technical University of Ostrava, 17. listopadu 15, 70833 Ostrava-Poruba, Czech Republic — [2]Department of Physics and Astronomy, Uppsala University, Box 516, 75121 Uppsala, Sweden

In this work we perform a systematic calculation of the Fe-Ta phase diagram. Despite of the fact that the two experimentally observed ordered Fe-Ta alloy phases do not exhibit magnetic properties suitable for permanent magnets (PMs), our computational study suggests that new phases, with intrinsic magnetic properties appropriate for PMs, might exist within this binary system. By using structure prediction methods based on evolutionary algorithms and density functional theory, we identify two energetically stable magnetic structures: a tetragonal Fe_3Ta (space group 122) and a cubic Fe_5Ta (space group 216) binary phases. The tetragonal structure is estimated to have both high saturation magnetization ($\mu_0 M_s$=1.14 T) and magneto-crystalline anisotropy (K_1=2.17 MJ/m^3) suitable for permanent magnet applications. In addition, we discover two metastable hard magnetic phases: Fe_5Ta_2 (space group 156) and Fe_6Ta (space group 194), that may exhibit intrinsic magnetic properties comparable to $SmCo_5$ and $Nd_2Fe_{14}B$, respectively. From the results of electronic structure calculations we determine electronic states responsible for such large MAE and identify a criterion to find hard magnetic structures in rare-earth free intermetallic systems.

MA 50.4 Thu 15:45 HSZ 101

Strong magnetocrystalline anisotropy and magnetic hardness at room-temperature in the rare-earth-free magnet Rh2CoSb — •Yangkun He[1], Gerhard Fecher[1], Rudolf Schaefer[2,3], S. S. P. Parkin[4], J. M. D. Coey[5], and Claudia Felser[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, D-01187 Dresden, Germany — [2]Institute for Materials Science, TU Dresden, D-01062 Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Helmholtzstrasse 20, D01069 Dresden, Germany — [4]Max Planck Institute of Microstructure Physics, Halle, Germany — [5]School of Physics, Trinity College, Dublin 2, Ireland

Strong uniaxial magnetocrystalline anisotropy is indispensable for a permanent magnet, but it is rarely achieved in rare-earth-free compounds. Here we report a magnetocrystalline anisotropy of 3.62 MJm-3 in single crystals of a tetragonal Heusler compound Rh2CoSb with a saturation magnetization of μ0Ms = 0.52 T at 2 K (2.20 MJm-3 and 0.44 T at room-temperature). The magnetic hardness parameter κ of 3.7 at room temperature is the highest observed for a rare-earth-free magnet. Strong anisotropy is also manifest in the transport properties; the values of electrical and thermal conductivities are twice as large along the c axis as along the a axis and there are significant differences of the anomalous Hall effect and magnetoresistance. Our study illustrates the benefits of designing highly anisotropic rare-earth-free magnets using 4d elements, with potential as future thin film media.

MA 50.5 Thu 16:00 HSZ 101

Influence of cooling conditions and alloy composition on the microstructure of NdFeB alloys for a deformation production route — •Corinna Müller[1], Franziska Staab[1], Fansun Chi[2], Peter Groche[2], Enrico Bruder[3], Karsten Durst[3], Stefan Riegg[1], and Oliver Gutfleisch[1] — [1]Funktionale Materialien, FB Materialwissenschaft, TU Darmstadt — [2]Institut für Produktionstechnik und Umformmaschinen, FB Maschinenbau, TU Darmstadt — [3]Physikalische Metallkunde, FB Materialwissenschaft, TU Darmstadt

NdFeB permanent magnets play a key role in renewable energy technologies because their use is required for efficient electric machines. The specific microstructure of these magnets is directly connected to their magnetic performance. The classical powder metallurgical production route uses jet milling and sintering to achieve homogeneous grain sizes of a few micrometers. The related processing costs are however rather high and the here introduced use of rotary swaging could be an alternative and cheaper technique, allowing continuous processing. During swaging in this top-down processing approach the grain size of a cast body is reduced by the deformation. In this work, experiments to microstructure optimization of the starting alloy precursor after casting are presented and compared to the classical powder metallurgical processing. The microstructure was manipulated by the casting mold geometries and the addition of different dopants. The aim is to understand the thermodynamic and kinetic properties of the process (cooling conditions, phase formation, size distribution) and derive an adequate starting microstructure for rotary swaging.

15 min. break.

MA 50.6 Thu 16:30 HSZ 101

Magnetic properties of "1-5" intermetallic compounds from first principles — •Olga Vekilova[1], Heike C. Herper[1], and Olle Eriksson[1,2] — [1]Uppsala University, Uppsala, Sweden — [2]Örebro University, Örebro, Sweden

Permanent magnets are of vital importance for sustainable industry and in particular, are parts of most of the sources of "green" energy. The $RECo_5$, so-called "1-5" intermetallic compounds with the hexagonal $CaCu_5$ structure, where RE represents the rare-earth elements, such as Ce, Sm, Gd, etc., have been attracting attention primarily due to their excellent magnetic properties. These magnets exhibit very high value of magnetocrystalline energy (MAE), the key intrinsic property for the applications[1]. However theoretical studies of $RECo_5$ are very limited due to difficulties in the description of localized 4f-states of RE-elements. One of the well-known examples is $GdCo_5$, where the symmetry of the Gd 4f shell causes crystal field effects to vanish [2]. The absence of crystal-field effects makes $GdCo_5$ a particularly useful system to study the rare-earth/transition-metal interaction via both theory and experiment. This system also has relatively high MAE, which can be further improved by doping and pressure. Using our improved theoretical methodology, we studied the magnetic properties of pure and doped 1-5 compounds. The results on magnetization, MAE, and Curie temperature will be presented and analyzed. We will also show how doping of $RECo_5$ allows changing of its magnetic properties in a controlled manner. [1] J. Phys.: Condens. Matter 30 195801 (2018) [2] Phys. Rev. Materials 3, 034409 (2019)

MA 50.7 Thu 16:45 HSZ 101

Interplay between chemical order and magnetic properties in $L1_0$ FeNi (tetrataenite): A First-Principles Study — •Ankit Izardar and Claude Ederer — Materials Theory, ETH Zuerich, Switzerland

The volatility in price and uncertainty of supply of rare earth elements has sparked great interest to explore permanent magnets that are free from rare-earth elements. One interesting candidate in this quest is a chemically-ordered $L1_0$ $Fe_{50}Ni_{50}$ found in iron meteorites. However, laboratory synthesis of the ordered phase is extremely challenging because of the slow diffusion of atoms at the rather low order-disorder transition temperature. Until now, only partially ordered samples have been synthesized. Therefore, it is important to know how deviations from perfect chemical order affect the magnetic properties.Using first-principles-based density-functional theory calculations in combination with Monte Carlo (MC) simulations, we investigate the interplay between chemical order and the magnetic properties of the $L1_0$ FeNi phase. We use a supercell approach to model structures with varying degree of chemical order in combination with the disordered local moment method to describe the paramagnetic state. Our calculations demonstrate a strong effect of the magnetic order on the chemical order-disorder transition temperature and vice-versa. Furthermore, we also investigate dependence of the magneto-crystalline anisotropy (MAE) on the chemical long range order. Our results indicate that small deviations from perfect order do not significantly decrease the MAE with respect to a completely ordered FeNi alloy.

MA 50.8 Thu 17:00 HSZ 101

Impact of magnetism on the phase stability of rare-earth based hard magnetic materials — •Halil Ibrahim Sözen, Tilmann Hickel, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung GmbH, 40237 Düsseldorf, Germany

In recent years, quantum-mechanically guided materials design has been successfully used to identify candidate hard magnetic materials with a reduced content of rare earth elements. These studies were restricted to identify optimal magnetic properties. In the present work we address the issue of thermodynamic stability of such materials, i.e., whether such materials can be actually formed. As prototype system we consider CeFe11Ti and focus on the impact of magnetism on the free energy. To this end, we use the magnetic model suggested by Gerhard Inden as a reference. The performance of this model is compared to Monte Carlo simulations for the magnetic entropy contribution. We conclude that despite the empirical nature of the Inden model, it provides a surprisingly accurate description of the magnetic contribution. Based on this approach we are able to faithfully predict the critical temperature for the decomposition of CeFe11Ti into competing Laves phases. We further show that the Inden model can be improved if the reduction of the magnetic moment at finite temperatures is taken into account. This is demonstrated for the hard magnetic phase Nd2Fe14B. In addition, the impact of magnetism on the lattice vibrations of relevant phases in the Ce-Fe-Ti system is analyzed.

MA 50.9 Thu 17:15 HSZ 101

Manipulation of intrinsic properties of $CeFe_{11}Ti$: Experiment and Theory — •Semih Ener[1], Anna Galler[2], Fernando Maccari[1], Imants Dirba[1], Konstantin P. Skokov[1], Silke Biermann[2], Leonid Pourovskii[2], and Oliver Gutfleisch[1] — [1]Functional Materials, Department of Materials Science, Technische Universität Darmstadt, Darmstadt/Germany — [2]Centre de Physique Théorique, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau/France

The abundance of rare-earth (RE) elements like Nd and Sm motivates researchers to look for alternative free-RE (like Ce, Pr, La) material systems. Interesting candidates are $ThMn_{12}$-phases where the RE concentration is lower in comparison to the benchmark material systems $Nd_2Fe_{14}B$ and Sm_2Fe_{17}. The $CeFe_{12}$ phase is not stable in bulk form, so additional elements need to be substituted for Fe to stabilize the phase. Among the alternative stabilization elements, titanium is a promising candidate due to its low composition ratio (approx. 7 at.% for stabilization of the $ThMn_{12}$-phase in bulk) for ternary concentrations. In this work, we carried out composition and thermal treatment optimization for the $Ce_{1+x}Fe_{11}Ti$ series and investigated the magnetic properties under positive and negative pressures. In addition to the experiments, first-principles dynamical mean-feld theory (DMFT) calculations were carried out. Intrinsic properties were investigated at different temperatures and will be presented in this work.

This work is supported by the DFG-ANR project RE-MAP (Project No. 316912154).

MA 51: Ultrafast Dynamics of Light-Driven Systems (joint session TT/MA)

Time: Thursday 15:00–17:45 Location: HSZ 201

MA 51.1 Thu 15:00 HSZ 201

Out-of-equilibrium magnetism of Sr_2IrO_4 and La_2CuO_4 — •Ekaterina Paerschke[1], Yao Wang[2], and Cheng-Chien Chen[3] — [1]Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [2]Department of Physics, Harvard University, Cambridge 02138, USA — [3]Department of Physics, University of Alabama at Birmingham, Birmingham, Alabama 35294, USA

Ultrafast pump-probe spectroscopy is an efficient tool to characterize and control strongly correlated materials due to its accessibility to both low-energy physics of the equilibrium phase and the novel excited states induced by the pump. Here, we investigate the ultrafast control of quantum magnetism in a half-filled Mott insulator, described by an extended Heisenberg model. This study reveals photo-manipulated magnetic properties for two archetypal Mott insulators: iridate Sr_2IrO_4 and cuprate La_2CuO_4. Understanding photo-manipulated spin fluctuations in cuprates and iridates can help to solve the long-standing question of superconductivity absence in the iridates, as spin fluctuations are believed to mediate superconductivity in transitional metal oxides. Starting from a broken-symmetry phase with a (π, π) ordering vector, we find that the various pump conditions can manipulate the competition with the subleading colinear AFM phase. Through the comparison of quantum quench simulations and Floquet analytical theory, we conclude that these manipulations are achieved through transient engineering of effective spin-exchange interactions.

MA 51.2 Thu 15:15 HSZ 201

Ultrafast spectroscopy of the Kitaev magnet $RuCl_3$ — •Raluca Aldea, Rolf B. Versteeg, Fumiya Sekiguchi, Anuja Sahasrabudhe, Kestutis Budzinauskas, Zhe Wang, and Paul H.M. van Loosdrecht — II. Physikalishes Institut, Universität zu Köln, Züplicher Str.77, Köln, Germany

Kitaev materials are a group of spin orbit assisted Mott insulators that bear strong bond-directional exchange interactions. This was discussed to result in a Kitaev liquid, implying that spins fractionalize in exotic Majorana fermion and Z_2 flux excitations. We use pump-probe spectroscopy in order to investigate the magnetization dynamics above and below the zigzag ordering temperature. We discuss the dynamics in terms of coupling between different degrees of freedom.

MA 51.3 Thu 15:30 HSZ 201

Ultrafast jamming transition in a charge-ordered system — •Yaroslav Gerasimenko[1,2], Jaka Vodeb[1], Jan Ravnik[1], Igor Vaskivskyi[1], Michele Diego[1], Viktor Kabanov[1], and Dragan Mihailoivic[1,2] — [1]Jozef Stefan Institute, Ljubljana, Slovenia — [2]CENN Nanocenter, Ljubljana, Slovenia

The combination of STM and in situ ultrafast excitation allows us to explore novel states of matter that can emerge from many-body interactions under highly non-equilibrium conditions. Most of such states are reminiscent of the nearby equilibrium ones. Here we show that a single femtosecond-scale optical pulse, applied to the prototypical transition metal dichalcogenide 1T-TaS2, can convert a perfect hexagonal charge order into a dramatically different metastable jammed state of strongly correlated electrons [1]. The mechanism for its formation is attributed to a dynamical localization of electrons through mutual interactions in absence of atomic disroder. We further build the phase diagaram of this transition as a function of fluence and temperature on multiple timescales. The time evolution of the localized charge pattern together with theoretical calculations [1, 2] confirm that charge order frustration is important for the state's unusual stability.

The work was supported by ARRS P1-0040 and ERC AdG "Trajectory".

[1] Ya. A. Gerasimenko et al., Nature Materials 18, 1078-1083 (2019)
[2] J. Vodeb et al., New J. Phys. 21, 083001 (2019)

MA 51.4 Thu 15:45 HSZ 201

Creating non-equilibrium orders in high-temperature superconductors — •Guido Homann[1], Jayson Cosme[1,2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien und Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, 22761 Hamburg, Germany

We simulate far-out-of-equilibrium dynamics in cuprate superconductors, such as YBCO, employing a semiclassical approach. Our approach combines relativistic c-field theory with a $U(1)$ lattice gauge theory, resulting in a 3D lattice of intrinsic Josephson junctions. Our description includes dissipation and thermal fluctuations. It constitutes an extension of 1D sine-Gordon models, due to the inclusion of amplitude dynamics and of in-plane fluctuations. We implement a variety of driving protocols, which address the plasmonic or phononic degrees of freedom, and explore the resulting non-equilibrium scenarios. As a central example, we apply our method to transient phenomena induced in pump-probe protocols, and compare to observed phenomena. This work extends and builds on previous studies reported in [1,2], and has its main focus on the creation of metastable superconducting states.

[1] J. Okamoto, A. Cavalleri, L. Mathey, Phys. Rev. Lett. **117**, 227001 (2016).
[2] J. Okamoto, W. Hu, A. Cavalleri, L. Mathey, Phys. Rev. B **96**, 144505 (2017).

MA 51.5 Thu 16:00 HSZ 201

Detecting superconductivity out-of-equilibrium — •Sebastian Paeckel[1], Benedikt Fauseweh[2,3], Alexander Osterkorn[1], Thomas Kohler[4], Dirk Manske[3], and Salvatore R. Manama[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [4]Department of Physics and Astronomy, Uppsala University, Box 516, S-751 20 Uppsala, Sweden

Recent pump-probe experiments on underdoped cuprates and similar systems suggest the existence of a transient superconducting state above T_c. This poses the question how to reliably identify the emergence of long-range order, in particular superconductivity, out-of equilibrium. We investigate this point by studying a quantum quench in an extended Hubbard model and by computing various observables, which are used to identify (quasi-)long-range order in equilibrium. Our findings imply that, in contrast to current experimental studies, it does not suffice to study the time evolution of the optical conductivity to identify superconductivity. In turn, we suggest to utilize time-resolved ARPES experiments to probe for the formation of a condensate in the two-particle channel.

15 min. break.

MA 51.6 Thu 16:30 HSZ 201

Phase-sensitive analysis of Higgs oscillations in quenched superconductors with time- and angle-resolved photo emission spectroscopy — •Lukas Schwarz and Dirk Manske — Max Planck Institute for Solid State Research

Higgs oscillations in nonequilibrium superconductors provide a unique tool to obtain information about the underlying order parameter. Several quantities like the absolute value, existence of multiple gaps and the symmetry of the order parameter can be encoded in the Higgs oscillation frequency. Most works so far concentrate on experiments, where momentum averaged quantities like the optical conductivity or third-harmonic effects in the transmitted light field are investigated, which does not allow to access all possible information contained in the Higgs oscillations. Here, we study the time-resolved spectral function measured in angle-resolved photo emission spectroscopy after quenching the system using a general approach. We analyze the induced oscillations all over momentum space to study the creation process of collective Higgs oscillations and we extract phase information of the order parameter from the oscillations of the spectral function.

MA 51.7 Thu 16:45 HSZ 201

Controlling subdominant pairing symmetries in pumped unconventional superconductors — •Marvin A. Müller[1], Pavel A. Volkov[1,2], Indranil Paul[3], and Ilya Eremin[1,4] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Germany — [2]Department of Physics and Astronomy, Center for Materials Theory, Rutgers University, Piscataway, New Jersey 08854, USA — [3]Laboratoire Matériaux et Phénomènes Quantiques, Université de Paris, CNRS, F-75013 Paris, France — [4]Institute of Physics, Kazan Federal University, Kazan 420008, Russian Federation

We investigate the short-time dynamics in superconductors with multiple attractive pairing channels out of equilibrium. Studying a single-band square lattice model with a spin-spin interaction as an example, we find the signatures of collective excitations of the subdominant pairing symmetries (known as Bardasis-Schrieffer modes) as well as the order parameter amplitude (Higgs mode) in the short-time dynamics of the spectral gap and quasiparticle distribution after an excitation by a pump pulse. We show that the polarization and intensity of the pulse can be used to control the symmetry of the nonequilibrium state as well as frequencies and relative intensities of the contributions of different collective modes. We find particularly strong effects of the Bardasis-Schrieffer mode in the dynamics of the quasiparticle distribution function and propose possible signatures in trARPES experiments.

MA 51.8 Thu 17:00 HSZ 201

Revealing Hund's multiplets in Mott insulators under strong electric fields — •Nagamalleswararao Dasari[1], Jiajun Li[1], Philipp Werner[2], and Martin Eckstein[1] — [1]Department of Physics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany — [2]Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland

We investigate the strong-field dynamics of a paramagnetic two-band Mott insulator using real-time dynamical mean-field theory. We demonstrate that strong electric fields can lead to a transient localization of electrons. This nonequilibrium quantum effect allows to reveal specific signatures of local correlations in the time-resolved photoemission spectrum. In particular, we demonstrate that the localization can be strong enough to produce atomic-like spin multiplets determined by the Hund's coupling J, and thus provide a way of measuring J inside the solid. Our simulation also fully incorporates non-linear field-induced tunnelling processes, which would lead to a dielectric breakdown in the steady state limit. A careful analysis of these processes however shows that they remain weak enough and do not prevent the measurement of the transiently localized spectra.

MA 51.9 Thu 17:15 HSZ 201

Ultrafast electronic correlations in ordered phases — •Riku Tuovinen[1], Denis Golež[2], Martin Eckstein[3], and Michael A. Sentef[4] — [1]QTF Centre of Excellence, Turku Centre for Quantum Physics, Department of Physics and Astronomy, University of Turku, 20014 Turku, Finland — [2]Center for Computational Quantum Physics, Flatiron Institute, 162 Fifth Avenue, New York, NY 10010, USA — [3]Department of Physics, University of Erlangen-Nürnberg, 91058 Erlangen, Germany — [4]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany

We consider many-body correlations in an excitonic-insulator system acting as a prototypical ordered-phase material [1]. Out-of-equilibrium dynamics in such systems with a symmetry-broken ground state has been shown to be extremely sensitive to all the intricacies in the electronic structure [2]. For an accurate description of the important and interesting mechanisms we take into consideration strong external fields, many-body correlations, and transient effects at an equal footing by the nonequilibrium Green's function technique [3]. We drive the system out-of-equilibrium by a laser pulse, and we compare the resolved dynamics between the Kadanoff-Baym equations and the computationally less expensive generalized Kadanoff-Baym Ansatz [4].

[1] S. Mor et al. Phys. Rev. Lett. 119, 086401 (2017)
[2] R. Tuovinen et al. Phys. Status Solidi B 256, 1800469 (2018)
[3] G. Stefanucci and R. van Leeuwen, Nonequilibrium Many-Body Theory of Quantum Systems, CUP (2013)
[4] R. Tuovinen et al. in preparation

MA 51.10 Thu 17:30 HSZ 201

Ultrafast metal-to-insulator switching in a strongly correlated system — •Francesco Grandi and Martin Eckstein — Department of Physics, University of Erlangen-Nürnberg, 91058 Erlangen, Germany

Several experiments have shown the possibility to induce an ultrafast insulator-to-metal phase transition in correlated materials. Instead, it remains debated how to experimentally realize an ultrafast phase transition in the opposite direction, i.e. a metal-to-insulator phase change. Developing a protocol that can lead to such a transition is relevant for the realization of a Mottronic device able to operate at the ultrafast time scales. A possible candidate for the realization of this scenario is the oxygen-enriched $LaTiO_{3+x}$, a correlated metal close to the Mott insulator $LaTiO_3$.
Here, we consider an effective model that we believe captures the main physical properties of $LaTiO_{3+x}$. We describe the photo-doping of electrons into the valence bands of the material from the low-lying oxygens 2p-derived band using non-equilibrium Dynamical Mean-Field Theory. By applying a suitably designed chirped-pulse that leads to dipolar excitations, we analyze how fast we can induce the metal-to-insulator transition and how far the final state is from a thermal configuration.

MA 52: Quantum Magnets and Molecular Magnets (joint session TT/MA)

Time: Thursday 15:00–18:00 Location: HSZ 304

Invited Talk MA 52.1 Thu 15:00 HSZ 304

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]. This, together with the strong field dependence of the spin reversal, allows creating 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 [3]. 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 Li_4SrN_2, $LiSr_2(CoN_2)$, $(Sr_6N)[FeN_2][CN_2]_2$, and K_2NiO_2.Implications and limitations of the 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] S. A. Bräuninger et al., arXiv:1909.12774

MA 52.2 Thu 15:30 HSZ 304

The power of typicality applied to magnetic molecules and low-dimensional quantum spin systems — •Jürgen Schnack — Universität Bielefeld, Fakultät für Physik

Molecular or low-dimensional quantum spin systems often prevent an exact calculation of their magnetic properties due to a prohibitively large size of the related Hilbert spaces. Typicality-based approaches such as the finite-temperature Lanczos method allow to investigate rather large systems with unprecedented accuracy. This way quantum critical as well as magnetocaloric properties of large cyclic clusters could be elucidated [1]. For the kagome lattice antiferromagnet it became possible to model a lattice of size N=42 (!) quasi exactly. This enabled us to study in particular that the low-lying density of singlet states moves up in energy contrary to common believe [2]. In addition, we could demonstrate for lattices up to 72 sites that magnon crystallization occurs slightly below the saturation field, an effect driven by the existance of flat energy bands [3].

[1] A. Baniodeh et al., npj Quantum Materials 3,10 (2018)
[2] J. Schnack, J. Schulenburg, J. Richter, Phys. Rev. B 98, 094423 (2018)
[3] J. Schnack, J. Schulenburg, A. Honecker, J. Richter, arXiv:1910.10448

MA 52.3 Thu 15:45 HSZ 304

Resonant photon absorption in $GdPc_2$ molecular magnet — •Gheorghe Taran[1], Eufemio Moreno-Pineda[2], Edgar Bonet[3], and Wolfgang Wernsdorfer[1,2,3] — [1]Physikalisches Institute, KIT, Karlsruhe — [2]Institute of Nanotechnology (INT), Karlsruhe — [3]Néel Institute, CNRS, Grenoble, France

Single ion molecular magnets (SIMMs) champion a magnetic center (*e.g.* a 3d or 4f ion) whose properties are modulated by the coordinated organic ligands. Their relative simple structure makes the task of correlating structural characteristics to physical properties considerably easier and thus, opens the doors for chemical tailoring for technological applications that range from refrigeration to storage and processing of quantum information.

In this study, we investigate the resonant photon absorption in diluted single crystals of $GdPc_2$ SIMM using micro-SQUID technique at subkelvin temperatures. Combining the advantages of EPR (*e.g.* the ability to explore the anisotropy character of the magnetic interactions) and those of micro-SQUID techniques (*e.g.* time-resolved dynamics on a micro-second scale) we construct the map of resonant transitions in the [1:40] GHz frequency range. The transitions are analyzed in the framework of a single spin Hamiltonian describing the ground state, $S = 7/2$, of the $GdPc_2$ complex and the predictions are compared to the ones made by ab-initio calculations. The unprecedented resolution of the resonant frequency-field maps allows a critical evaluation of the state of the art ab-initio methods for ligand field estimations and sets the base for future investigations into the coherent dynamics.

MA 52.4 Thu 16:00 HSZ 304

Quantum magnetism in Boleite - an Archimedean Solid with strong magnetic frustration — Stefan Lebernegg[1,2], Jürgen Schnack[3], Oleg Janson[4], Johannes Richter[5], Jörg Sichelschmidt[2], Tobias Förster[6], Alexander Tsirlin[7], and •Helge Rosner[2] — [1]Technical University of Munich, 80335, Munich, Germany — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany — [3]Bielefeld University, Faculty of Physics, Universitätsstr. 25, D-33615 Bielefeld, Germany — [4]IFW Dresden Helmholtzstraße 20 01069 Dresden Germany — [5]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden Germany — [6]Dresden High Magnetic Field Laboratory — [7]Experimental Physics VI, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Combined theoretical and experimental effort, applying electronic structure calculations and numerical simulations as well as chemical analysis, X-ray diffraction and magnetic measurements had to be joined by mineralogical expertise to unveil the quantum magnetism of the mineral Boleite. This mineral is a strongly frustrated quantum magnet with 24 spin 1/2 Cu sites arranged on the vortices of a truncated cube, one of the famous Archimedean solids. We find that the system with its typical 1/3 magnetization plateau can be well understood by two leading interactions and their "randomness" describing a certain distribution of these exchange interactions.

MA 52.5 Thu 16:15 HSZ 304

Multi band modelling of exchange couplings in edge-sharing Cu-O chains — •Dijana Milosavljevic[1], Oleg Janson[2], Jan Tomczak[3], and Helge Rosner[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden — [2]IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [3]Technical University of Vienna, Austria

One of the structural features that has a crucial role in the determination of the exchange coupling constant in chain containing compound is the Cu-O-Cu bond angle. However the angle is not the only factor. Equally important influence on the exchange coupling has the presence of the side groups coupled to the O-ligands. To demonstrate this we show two representatives of edge sharing chain cuprates with similar Cu-O-Cu bond angles but drastically different exchanges. From detailed DFT studies and subsequently derived multi band tight binding models we find that the crucial parameter is the difference in onsite energies of ligand O $2p_x$ and O $2p_y$ orbitals parallel and perpendicular to the Cu-O chain. Using this parameter, a microscopic explanation for the drastically different magnetic exchanges can be established. To illustrate the crucial influence of side groups we provide examples of H-containing compounds where a rotation of H even leads to a sign change of the superexchange interaction from strongly ferromagnetic to strongly antiferromagnetic.

15 min. break.

MA 52.6 Thu 16:45 HSZ 304

Field tunability of BKT correlations in the square-lattice Heisenberg antiferromagnet CuPOF — •D. Opherden[1,2], C. P. Landee[3], F. Bärtl[1,2], M. Uhlarz[1], Y. Skourski[1], A. N. Ponomaryov[1], S. A. Zvyagin[1], J. Wosnitza[1,2], and H. Kühne[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Department of Physics, Clark University, Worcester, Massachusetts, USA

The metal-organic compound $[Cu(pz)_2(2\text{-}OHpy)_2](PF_6)_2$ (CuPOF) is a molecular-based realization of the 2D square-lattice $S = \frac{1}{2}$ Heisenberg antiferromagnet with well-separated Cu(pz) layers and a moderate intraplane coupling $J/k_B = 6.8$ K. We present a focus study of the low-T phase transition to long-range order, performed via ^{1}H and ^{31}P nuclear magnetic resonance and bulk magnetometry. A weak intrinsic easy-plane anisotropy, revealed by magnetization data, yields a temperature-driven crossover of the spin-exchange anisotropy from isotropic Heisenberg to anisotropic XY-type behavior. The application of a magnetic field normal to the easy-plane yields a field-driven increase of the magnetic anisotropy with the occurrence of Berezinskii-Kosterlitz-Thouless correlations, revealed by results of the ^{31}P spin-lattice relaxation rate close to the transition temperature to long-range order. A detailed analysis of the temperature-dependent order parameter demonstrates the possibility for a continuous tuning of the spin-exchange anisotropy in CuPOF, from almost ideal isotropic Heisenberg to nearly XY-type exchange at elevated fields.

MA 52.7 Thu 17:00 HSZ 304

Y-, La- and Lu-Agardite, preparation, crystal structure, vibrational and low-dimensional magnetic properties — •Aleksandr M. Golubev[1], Eva Brücher[1], Armin Schulz[1], Reinhard K. Kremer[1], Robert Glaum[2], and Myung-Hwan

WHANGBO[3] — [1]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart, Germany — [2]Institut für Anorganische Chemie, Universität Bonn, 53121 Bonn, Germany — [3]Department of Chemistry North Carolina State University Raleigh, North Carolina 27695-8204, USA

We have prepared polycrystalline samples of Y, La- and Lu-agardite with composition $RECu_6(OH)_6(AsO_4)_3 \cdot n\ H_2O$ (RE = Y, La, Lu; n ≈ 3) and characterized their structural and vibrational properties as well as the magnetic behavior of the Cu^{2+} entities. The arsenates $RECu_6(OH)_6(AsO_4)_3 \cdot n\ H_2O$ (RE = Y, La, Lu; n ≈ 3) are isostructural with the mineral mixite and crystallize with a hexagonal structure which contains ribbons of edge-sharing $[CuO_5]$ square-pyramids extending along the hexagonal axis. They interconnect via $(AsO_4)^{3-}$ groups to form hexagonal tubes of about 10 Å inner diameter. Such zeolite-like tubes host water molecules, which can be reversibly removed at moderate temperature (≈ 100 °C). Like in mixite the Cu^{2+} cations in $RECu_6(OH)_6(AsO_4)_3 \cdot n\ H_2O$ (RE = Y, La, Lu; n ≈ 3) exhibit low-dimensional antiferromagnetic properties the character of which is subject to changes in the Cu-O-Cu bonding distances and bonding angles due to the lanthanide contraction. DFT calculations indicate that the strongest spin exchange pathways couple the Cu^{2+} S=1/2 magnetic moments predominantly within the hexagonal tubes.

MA 52.8 Thu 17:15 HSZ 304

Quantum phase transitions of Ising ferromagnets in tilted transverse fields — •HEIKE EISENLOHR and MATTHIAS VOJTA — Institut für theoretische Physik, Technische Universität Dresden, Germany

Transverse-field Ising magnets constitute a paradigmatic example for quantum phase transitions, with experimental realisations in e.g. $LiHoF_4$ and $CoNb_2O_6$. Here we theoretically analyze the fate of the field-driven zero-temperature transition upon tilting the field away from the direction perpendicular to the easy axis. While the transition turns into a crossover if the ordered phase is single-domain, a sharp transition remains in the multi-domain case relevant for a ferromagnet. We characterize this transition in detail, also discussing effects of domain-wall motion. Upon including nuclear spin degrees of freedom, we are able to link our results to experiments on $LiHoF_4$.

MA 52.9 Thu 17:30 HSZ 304

Chemical design strategies and field-induced phases in antiferromagnetically coupled organic spin-dimer systems — •BERND WOLF[1], LARS POSTULKA[1], PAUL EIBISCH[1], ULRICH TUTSCH[1], MARTIN BAUMGARTEN[2], and MICHAEL LANG[1] — [1]Physics Institute, Goethe-University, SFB/TR49, D-60438 Frankfurt (M) — [2]Max-Planck-Institute for Polymer Research, SFB/TR49, D-55128 Mainz

Coupled antiferromagnetic spin-dimer systems based on the stable organic radical units nitronyl-nitroxide (NN) and imino-nitroxide (IN) are recognized as suitable candidates for exploring critical phenomena under well-controlled conditions. For these systems the *intra*- and *inter*-dimer magnetic exchange interactions can be modified in specific ways. Depending on the geometry of the *inter*-dimer couplings, various scenarios can be observed. We discuss the magneto-structural correlations of selected materials based on tolan molecules linked together with NN- and IN-units. Furthermore, using low-temperature ac susceptibility and specific heat measurements we characterize the field-induced magnetic phases of these materials and discuss their critical behavior. In addition, we present a new approach for designing intermolecular magnetic exchange interactions based on planar π-bridges of benzo[1,2 -*b*:4,5 -*b'*] dithiophene derivatives which connect the stable NN and IN radical units. Our results demonstrate that π-stacking of the planar bridges allows a good control of the *inter*-molecular magnetic exchange.

MA 52.10 Thu 17:45 HSZ 304

Field-induced magnetic phase in quasi-one-dimensional $YbAlO_3$ — •STANISLAV NIKITIN[1,2], LIUSUO WU[3], ALEKSANDR SUKHANOV[1,2], NIKOLAY PAVLOVSKIY[4], JIANHUI XU[5], MANUEL BRANDO[1], LEONID VASYLECHKO[6], and ANDREY PODLESNYAK[7] — [1]Max Planck Institute CPfS, Dresden, Germany — [2]Technical University Dresden, Germany — [3]Southern University of Science and Technology, Shenzhen, China — [4]Kirensky Institute of Physics, Krasnoyarsk, Russia — [5]Helmholtz-Zentrum Berlin, Berlin, Germany — [6]Lviv Polytechnic National University, Lviv, Ukraine — [7]Oak Ridge National Laboratory, TN , USA

The antiferromagnetic Heisenberg S = 1/2 chain in magnetic field is one of the simplest model, which exhibits quantum critical behavior. In finite magnetic field below the QPT, a weak interchain interaction can stabilize an incommensurate spin-density wave phase, which propagation vector can be continuously tuned by magnetic field.

$YbAlO_3$ is a quasi-1D spin chain compound, where Yb moments form spin chain along the *c*-axis. In this work we studied excitation spectrum and magnetic structure of this materials by means of neutron scattering in magnetic field. We found that the excitation spectra are well described by simple Heisenberg model in magnetic field. However, in contrast to the simple spin-density wave ordering with propagation vector $\mathbf{q} = 2k_F$ as predicted by the Heisenberg model, the magnetic structure shows more complex behavior and drastically changes at $M/3$ plateau. We discuss a possible theory explanation for this behavior.

MA 53: Magnonics II

Time: Thursday 15:00–16:45 Location: HSZ 401

MA 53.1 Thu 15:00 HSZ 401

Quantum spin transfer due to spin shot noise — •ALIREZA QAIUMZADEH and ARNE BRATAAS — Center for Quantum Spintronics, Norwegian University of Science and Technology

Recent measurements in current-driven spin valves demonstrate magnetization fluctuations that deviate from semiclassical predictions. We posit that the origin of this deviation is spin shot noise. On this basis, our theory predicts that magnetization fluctuations asymmetrically increase in biased junctions irrespective of the current direction. At low temperatures, the fluctuations are proportional to the bias, but at different rates for opposite current directions. Quantum effects control fluctuations even at higher temperatures. Our results are in semiquantitative agreement with recent experiments and are in contradiction to semiclassical theories of spin-transfer torque [1].

[1] Phys. Rev. B 98, 220408(R) (2018)

MA 53.2 Thu 15:15 HSZ 401

Spin transport through insulating multilayers — •VERENA BREHM[1], ULRIKE RITZMANN[2], MARTIN EVERS[1], and ULRICH NOWAK[1] — [1]University of Konstanz, D-78457 Konstanz — [2]Freie Universität Berlin, D-14195 Berlin

Spin transport in magnetic insulators allows transport without Joule heating. Furthermore, many magnetic insulators are oxides with exceptionally low damping, giving rise to energy efficient transport for future spin-wave based technology. The design of spin-transport based devices such as transistors or spin valves often requires multilayer systems composed of different magnetic materials [1]. Thus, the understanding of the behavior of a spin current propagating across interfaces is crucial.

We study spin transport in two and three layer systems composed of ferro- and antiferromagnets within a classical atomistic spin model numerically. The focus of this talk is on the transmission of a spin current across the interfaces depending on the magnon frequency and on the interface and bulk properties. Furthermore, we investigate the temperature dependence of this transport, in particular for structures where the critical temperature varies significantly between the layers. This allows to study spin transport in the vicinity of the critical temperature, as demonstrated in recent experiments [2].

[1] Cramer et al.: Nat. Commun. **9**, 1089 (2018)
[2] Schlitz et al.: Appl. Phys. Lett. **112**, 132401 (2018)

MA 53.3 Thu 15:30 HSZ 401

Magnon-magnon interactions and how to calculate them in a magnetic film — •HALYNA YU. MUSIIENKO-SHMAROVA[1], VASYL S. TYBERKEVYCH[2], ANDREY N. SLAVIN[2], ALEXANDER A. SERGA[1], and BURKARD HILLEBRANDS[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaisersalutern, Germany — [2]Department of Physics, Oakland University, Rochester, Michigan 48309, USA

Elementary magnetic excitations, often called spin waves or magnons, are widely used in spintronics and magnonics signal processing devices, as they are able to transport energy and spin angular momentum over long distance. Furthermore, recently, fundamental phenomena such as magnon Bose-Einstein condensation, magnonic supercurrents, and Bogoliubov waves were discovered in the field of spin-wave physics. Such processes strongly depend on the interactions between magnons, which can be described using corresponding nonlinear coefficients (nonlinear energy terms of spin-wave Hamiltonian). Besides, the values of these coefficients crucially influence the formation of nonlinear spin-wave objects such as solitons, bullets and droplets. Here, we present a new theoretical approach for the description of weakly nonlinear magnetization excitations. This method allows to directly determine the values of eigenfrequencies and eigenmodes of magnetic excitations and magnon-magnon interaction coefficients in yttrium iron garnet films of different thicknesses for different values and directions of the external magnetic field. Financial support from the ERC Advanced Grant "SuperMagnonics" is acknowledged.

MA 53.4 Thu 15:45 HSZ 401

Stabilizing Bose-Einstein condensation of magnons in ultrathin films using spatial confinement — •Morteza Mohseni[1], Alireza Qaiumzadeh[2], Alexander A. Serga[1], Arne Brataas[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

A high density of interacting quasi particles (QPs) can undergo a phase transition to form a new phase of matter known as the Bose Einstein condensate (BEC). It has been predicted that a magnon BEC cannot be stabilized in extended ultrathin insulating magnets of yttrium iron garnet (YIG) [1]. Here, we introduce a new way to stabilize a magnon BEC in an ultrathin film by spatial confinement. Using numerical simulations, we present the formation of a magnon BEC in an ultrathin YIG microconduit and explore the nonlinear scattering processes behind the BEC formation in our system. We show how quantized thermalization channels allow the BEC formation in our confined element. Moreover, we investigate the role of dipolar interactions on the BEC stability in our system. Our results provide new insight into strongly nonlinear spin dynamics in ultrathin films, and further introduce a nontrivial mechanism to obtain BEC stability in nanoscale devices. 1. I. S. Tupitsyn, et al., Phys. Rev. Lett. 100, 257202 (2008)

MA 53.5 Thu 16:00 HSZ 401

Room-temperature magnon Josephson oscillations — •Alexander J. E. Kreil[1], Anna Pomyalov[2], Victor S. L'vov[2], Halyna Yu. Musiienko-Shmarova[1], Gennadii A. Melkov[3], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Faculty of Radiophysics, Electronics and Computer Systems, Taras Shevchenko National University of Kyiv, Kyiv 01601, Ukraine

The alternating current (ac) Josephson effect is known as a rapidly oscillating current, which appears between weakly coupled macroscopic quantum states, such as superconducting states subject to an external dc voltage. So far, this phenomenon was observed at cryogenic temperatures in superconductors, in superfluid helium, and in Bose-Einstein condensates (BECs) of trapped atoms. A similar effect is expected in a magnon BEC at room-temperature. Here, we report on the experimental discovery of the ac Josephson effect in a magnon BEC carried by a room-temperature ferrimagnetic film. We suggest a theoretical model that adequately describes the observed supercurrent flow, which itself manifests as oscillations in the magnon BEC density and supports the findings.

MA 53.6 Thu 16:15 HSZ 401

Amplification of propagating spin waves by rapid cooling — •Michael Schneider[1], David Breitbach[1], Bert Lägel[1], Carsten Dubs[2], Halyna Musiienko-Shmarova[1], Dmytro A. Bozhko[3], Alexander A. Serga[1], Andrei N. Slavin[4], Vasyl S. Tiberkevich[4], Burkard Hillebrands[1], and Andrii V. Chumak[5] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany — [3]Department of Physics and Energy Science, University of Colorado at Colorado Springs, Colorado Springs, USA — [4]Department of Physics, Oakland University, Rochester, USA — [5]Faculty of Physics, University of Vienna, Austria

Recently we reported on the formation of a magnon Bose-Einstein Condensate triggered by a non-equilibrium between the magnon and the phonon system, achieved by rapid cooling of magnonic nano-structures. Here we report on the interaction of a propagating spin-wave with such a non-equilibrated system. The rapid cooling of a preheated, confined region of a micro scaled waveguide results in a redistribution of magnons to lower energies. During this, a spin-wave pulse propagating through the rapidly cooled area gets amplified. This amplification process is investigated with respect to the strength of the non-equilibrium and the delay between the spin-wave packet and the formation of the non-equilibrium. This research has been supported by ERC StG 678309 MagnonCircuits, ERC AdG 694709 SuperMagnonics and DFG Grant DU 1427/2-1.

MA 53.7 Thu 16:30 HSZ 401

Twisting and tweezing the spin wave: on helical waves, and the magnonic spiral phase plate — •Alexander F. Schäffer[1], Decheng Ma[2], Chenglong Jia[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle (Saale), Germany — [2]Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education & Institute of Theoretical Physics, Lanzhou University, China

Spin waves are the low-energy excitations of magnetically ordered materials. They are key elements in the stability analysis of the ordered phase and have a wealth of technological applications. Recently[1], we showed that spin waves of a magnetic nanowire may carry a definite amount of orbital angular momentum components along the propagation direction. This helical, in addition to the chiral, character of the spin waves is related to the spatial modulations of the spin wave phase across the wire. It, however, remains a challenge to generate and control such modes with conventional magnetic fields. Therefore, we propose a magnetic heterostructure that acts as a magnetic spiral phase plate by appropriately synthesizing two magnetic materials that have different speeds of spin waves[2]. In this contribution, we discuss the key features of helical spin waves and demonstrate the functionality of the magnonic spiral phase plate with micromagnetic simulations.

[1] C. Jia, D. Ma, A. F. Schäffer, J. Berakdar, Nat. Commun. 10, 2077 (2019).

[2] C. Jia, D. Ma, A. F. Schäffer, J. Berakdar, J. Opt. 21, 12 (2019).

MA 54: Spin: Transport, Orbitronics and Hall Effects II

Time: Thursday 15:00–17:45 Location: HSZ 403

MA 54.1 Thu 15:00 HSZ 403

Temperature dependence of the Spin-Charge Conversion in Highly-doped π-conjugated Polymer PBTTT — •Mohammad Qaid[1], Olga Zadvorna[2], Henning Sirringhaus[2], and Georg Schmidt[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle — [2]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom

We present an intensive study addressing the temperature dependence of the spin-to-charge conversion in highly doped π-conjugated polymer PBTTT. The polymer is deposited on a ferrimagnetic YIG thin film and doped with F4TCNQ [1]. In ferromagnetic resonance a spin current is injected from the YIG into the PBTTT and the ISH-voltage is measured in the organic semiconductor. We have performed an ISHE thickness-dependence study at low temperatures which provides insight into the spin relaxation mechanisms in PBTTT. This study enabled us to extract some of the key parameters of the spin relaxation in highly-doped PBTTT, namely spin diffusion length and spin relaxation time. Our results indicate that the spin relaxation in PBTTT can be explained by Elliot-Yafet mechanism. Besides that, the change of the spin life-time with temperature indicates that the spin is more likely conserved in the hopping events and the spin flip occurs at the thermally reduced trapping events.

References [1]- Wang, Shu-Jen, et al, Nature Electronics 2, 98-107(2019)

MA 54.2 Thu 15:15 HSZ 403

Paramagnetic molecules on Fe_3O_4 as a spin-current detector — •Tanja Strusch[1], Ralf Meckenstock[1], Yulia Nalench[2], Maxim Abakumov[2], Michael Farle[1], and Ulf Wiedwald[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany — [2]National University of Science and Technology NUST MISIS, Moscow, Russian Federation

Pure spin current based devices are considered for future low dissipation electronics. An interfacial molecular paramagnet has been used as a spin current detector (IMPSD) [1] as an alternative detection scheme for the inverse spin Hall effect [2]. We extended the IMPSD to enhance the sensitivity, by enclosing an electron spin resonance (EPR) marker to a ferromagnetic interface which has two overlapping distinguishable EPR centers. Thus, we detect the influence of the spin current on the EPR centers resulting in an additional contribution to the power dependence of the two EPR modes. The chosen sample system is a Fe_3O_4 nanoparticle (NP) with oleic acid (OA) as a surfactant. The first EPR mode S1 is directly located at the OA-Fe_3O_4 interface and the second S2 at the double bond in the carbon chain [1]. If the ferromagnetic resonance of the Fe_3O_4-NP is tuned to the resonance field of the EPR line S1 (short lifetime), the number of excited paramagnetic centers increased. Due to the larger lifetime of S2 the additional excitation of S1 leads to an even stronger excitation of S2.

[1] T. Marzi et al., Phys. Rev. Applied 10, 054002 (2018).
[2] E. Saitoh et al., Appl. Phys. Lett. 88, 182509 (2006).

MA 54.3 Thu 15:30 HSZ 403

Phenalenyl-based Organic Barriers for Tunnel Junctions — •Neha Jha[1], Christian Denker[1], Anand Pariyar[2], Pavan K. Vardhanapu[2], Heba S. Mohamad[1], Amir Azinfar[1], Arne Ahrens[3], Ulrike Martens[1], Christiane A. Helm[1], Michael Seibt[3], Swadhin K. Mandal[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Germany — [2]Department of Chemical Sciences, IISER, Kolkata, India — [3]IV. Physikalisches Institut, Universität Göttingen, Germany

Phenalenyl (PLY) based molecules are appealing for spintronics as demonstrated by the formation of a spinterface, showing tunnel magneto-resistance close to room temperature [1].

Here, we compare different kinds of molecules (PLY, ZMP, PLY-Cu[2]) as barrier material. In addition, we introduce a new 3-D shadow mask technology allowing for junction sizes down to 3x6 μm^2. AFM and TEM imaging indicate sharp interfaces. Consequently, the current depends non-linearly on the voltage. The resistance depends exponentially on the barrier-thickness and shows no significant temperature dependence. This evidences tunneling as conduction mechanism. Magneto-resistive characteristics appear applying a few mV, while memristive properties require voltages in the volt range. Memristive resistance changes up to a factor of 2 are found for all three types of PLY, while magneto-resistive changes differ for the types of molecules and can also be as high as a factor of 2.

[1] K. V. Raman et al., Nature 493, p. 509 (2013)
[2] A. Mukherjee et al., J. Chem. Sci., 123, p. 139 (2011)

MA 54.4 Thu 15:45 HSZ 403

Conductivity and Hall effect in a ferromagnetic kagome metal Fe_3Sn_2 — •Lilian Prodan[1,2], Vladimir Tsurkan[1,2], and István Kézsmárki[1] — [1]EP V, EKM, University of Augsburg, D-86135 Augsburg, Germany — [2]Institute of Applied Physics, MD-2028 Chisinau, Moldova

Metallic ferromagnet Fe_3Sn_2 with a rhombohedral *R-3m* structure and a kagome lattice of Fe ions is promising to host massive Dirac fermionic states and topological magnon bands. We report the preparation, as well as magnetization, magnetoresistance and Hall effect measurements on Fe_3Sn_2 single crystals. The longitudinal resistivity ρ_{xx} shows a metallic behavior with a residual resistivity ratio ρ_{300K}/ρ_{2K} varying between 15 and 30, depending on the quality of samples. Both longitudinal and transverse magnetoresistance (MR) for magnetic fields H perpendicular to the *c*-axis are negative in the temperature range 305-50 K and become positive below 50 K. The transverse MR for H parallel to the *c*-axis is significantly higher than for the in-plane configuration and reaches 14% at 10 K in 9 T. The Hall effect measurements revealed a significant anomalous contribution at 300 K which decreases with decreasing of temperature. A quadratic dependence of the anomalous Hall resistivity on longitudinal resistivity was observed. The experimental data were analyzed with particular attention to intrinsic and extrinsic contributions to anomalous Hall conductivity related to Berry-phase and extrinsic mechanisms, respectively.

MA 54.5 Thu 16:00 HSZ 403

Spin orbit torques in Weyl semimetal /Ferromagnet and TMDC/ Ferromagnet bilayers — •Avanindra Kumar Pandeya, Amilcar Bedoya Pinto, Banabir Pal, Pranava Keerthi Sivakumar, Binoy Krishna Hazra, and Stuart Parkin — Max Planck Institute of Microstructure Physics

Weyl semimetals (WSMs) and Transition Metal Dichalcogenides (TMDCs) are two classes of quantum materials that are expected to have high spin-to-charge conversion efficiency. We have grown TaP/Py and NbSe2/Py bilayers using molecular beam epitaxy (MBE) which gives us precise control of the layer thickness and high-quality interfaces required for efficient spin transfer and spin-to-charge conversion experiments. In this work, we use the second harmonic Hall measurement to explore the spin-orbit torques (SOTs) produced by the WSMs and the TMDCs. We disentangle the different torque contributions by performing angular and field-dependent measurements in the bilayer devices, extracting the net spin-orbit torques related to effective charge-to-spin conversion efficiency in both material systems. Finally, we compare our results with the ones obtained by a different technique i.e. spin-torque ferromagnetic resonance (ST-FMR).

15 min. break.

MA 54.6 Thu 16:30 HSZ 403

New Interpretation of the High-field Magnetoresistance of Graphite — •Christian Eike Precker and Pablo David Esquinazi — Division of Superconductivity and Magnetism, Felix Bloch Institute, University of Leipzig, Leipzig, Germany.

The study of electrical properties in graphite shows that every sample exhibits differences between each other due to the contribution of 2D interfaces that are not homogeneously distributed. For thick enough samples, where the contribution of 2D interfaces always takes place, the magnetic field dependence shows qualitatively the same behavior, namely: at low fields the samples show a positive magnetoresistance, reaching a maximum at some field, which is sample dependent (normally between 15 T and 30 T). At fields above that maximum a negative magnetoresistance appears. At higher fields ($B \sim 40$ T), electronic phase transitions mounted on the negative magnetoresistance appear. With a parallel resistance model we can clarify several details of this complicated behavior. Our results indicate that the high conducting 2D interfaces are the main reason for the behavior observed in the high field magnetoresistance of graphite.

MA 54.7 Thu 16:45 HSZ 403

Record-breaking Magnetoresistance at the Edge of a Microflake of Natural Graphite — •Christian Eike Precker[1], José Barzola-Quiquia[1], Pablo David Esquinazi[1], Markus Stiller[1], Mun Chan[2], Marcelo Jaime[2], Zhipeng Zhang[3], and Marius Grundmann[3] — [1]Division of Superconductivity and Magnetism, Felix Bloch Institute, University of Leipzig, Leipzig, Germany. — [2]National High Magnetic Field Laboratory, Los Alamos National Laboratory, Los Alamos NM, USA. — [3]Semiconductor Physics Group, Felix Bloch Institute, University of Leipzig, Leipzig, Germany.

Using reactive ion etching on a micrometer-sized Sri Lankan natural graphite sample, sharp edges were created and several electrodes were placed parallel to the *c* axis at distances comparable to the size of the internal crystalline regions. Electrical transport measurements in this configuration revealed record values for the change of the resistance under applied magnetic field. At low temperatures and at $B \sim 21$ T the magnetoresistance (MR) reaches $\sim 10^7$ %. The MR values exceed by far all earlier reported ones for graphite and they are comparable or even larger (at $T > 50$ K) than the largest reported in solids including the Weyl semimetals. The origin of this large MR lies in the way the electrodes were build, sensing regions with the existence of highly conducting 2D interfaces aligned, parallel to the graphene planes.

MA 54.8 Thu 17:00 HSZ 403

Excitation of spin superfluids in easy-plane magnets —

•Martin Evers and Ulrich Nowak — University of Konstanz, D-78457 Konstanz

It is long known that easy-plane magnets exhibit an order parameter with SO(2) symmetry, which is equivalent to the U(1) gauge symmetry of the macroscopic wave function of a Bose condensate. For small out-of-plane components the magnetic equations take then a form similar to the Gross-Pitaevski equation, describing the time evolution of a Bose condensate and, hence, superfluidity. Because of this very resemblance, there is a specific type of transport in such magnets called "spin superfluidity" [1-2]. It is characterized by a well defined precession frequency ω_0 for all spins and a spin accumulation that spans under ideal conditions over the entire magnet. ω_0 basically sets the strength of the spin-superfluid excitation, addressed in this talk.

In a first step we analytically estimate ω_0 of spin superfluids in easy-plane ferro- and antiferromagnets. The next step is use atomistic spin simulations to investigate the excitation with respect to changes in the driving strength and the geometry not covered by the analytical theory. We find that in particular the exact geometry of the excited magnet does play a major role on the resulting spin-superfluid response. However, ferro- and antiferromagnets behave in almost aspect very much alike, expect for a lower spin accumulation in antiferromagnets. [3]

[1] B. I. Halperin et al., Phys. Rev. **188**, 898 (1969)
[2] S. Takei et al., Phys. Rev. Lett. **112**, 227201 (2014)
[3] M. Evers et al., arXiv: 1911.12786

MA 54.9 Thu 17:15 HSZ 403

Origin of the Magnetic Spin Hall Effect: Spin Current Vorticity in the Fermi Sea — •Alexander Mook[1], Robin Richard Neumann[2], Annika Johansson[2], Jürgen Henk[2], and Ingrid Mertig[2,3] — [1]Department of Physics, University of Basel, CH-4056 Basel — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [3]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

The interplay of spin-orbit coupling and magnetism gives rise to a plethora of charge-to-spin conversion phenomena that harbor great potential for spintronics applications. In particular, in addition to the spin Hall effect, magnets may exhibit a magnetic spin Hall effect [1,2].

Herein [3], we unveil the origin of the magnetic spin Hall effect and connect it to the spin current vorticity, i.e., to the tendency of the spin current to rotate, shear or curve in reciprocal space. This suggests the following illustrative explanation: Magnetic materials feature spin current whirlpools (or vortices) in reciprocal space for each of the three spin directions. Similar to water whirlpools (in real space), whose handedness leads to an asymmetric deflection of plane water waves, the spin current whirlpools (in reciprocal space) cause an asymmetric deflection of the respective spin components.

[1] J. Železný *et al.*, Phys. Rev. Lett. **119**, 187204 (2017); [2] M. Kimata *et al.*, Nature **565**, 627-630 (2019); [3] A. Mook, R. R. Neumann, A. Johansson, J. Henk, and I. Mertig, preprint arXiv:1910.13375

MA 54.10 Thu 17:30 HSZ 403

Magnetization dynamics in nanofiber networks — •Tomasz Blachowicz[1], Pawel Steblinski[1,2], Jacek Grzybowski[1], and Andrea Ehrmann[3] — [1]Silesian University of Technology, Institute of Physics - Center for Science and Education, 44-100 Gliwice, Poland — [2]Faculty of Electronics and Informatics, Koszalin University of Technology, 75-453 Koszalin, Poland — [3]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, Bielefeld, Germany

Magnetic nanofibers are of high interest for applications like data transport and storage as well as in basic research. Especially bent nanofibers, as they can unambiguously be produced by electrospinning [1], show a broad spectrum of possible magnetization reversal processes, depending on bending radius, geometry, magnetic field orientation, etc. [2].

Besides these quasistatic processes, dynamic investigations are necessary for investigating data transport properties of magnetic nanofibers. We report on domain wall transport through nanowires with different bending radii, starting from single nanowires to networks with multiple data inputs and outputs. Our results show diverse phenomena which have to be taken into account during these dynamic processes, such as domain wall instabilities or interference between converging signals, and suggest possible architectures of nanowire-based logics.

[1] C. Döpke, T. Grothe, P. Steblinski, M. Klöcker, L. Sabantina, D. Kosmalska, T. Blachowicz, A. Ehrmann, Nanomaterials 9, 92 (2019)
[2] T. Blachowicz, A. Ehrmann, J. Appl. Phys. 124, 152112 (2018)

MA 55: Non-Skyrmionic Magnetic Textures

Time: Thursday 15:00–17:15 Location: POT 6

MA 55.1 Thu 15:00 POT 6

Hall effects in non-collinear kagome antiferromagnets. — •Oliver Busch[1], Börge Göbel[1,2], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Max-Planck-Institut für Materialforschung, D-06120 Halle

By the end of the 19th century E. Hall discovered the anomalous Hall effect that usually occurs in metals in the ferromagnetic phase. The transversal electric conductivity exists without an external magnetic field and often scales with the magnetization.

In non-collinear antiferromagnets that do not have a net magnetization an anomalous Hall effect has been predicted as well and it has been measured in Mn_3Sn recently [1,2]. Furthermore it has been shown that in such materials the spin-Hall effect can exist even without spin-orbit coupling.

We examine a 2D kagome lattice considering a double-exchange s-d-tight-binding model. Our Hamiltonian includes the interaction of s electrons with non-collinear magnetic moments of a magnetic texture and spin-orbit coupling. Based on this we apply Kubo formalism to calculate the intrinsic contribution to the anomalous and spin-Hall conductivities. Furthermore we vary the magnetic moments' in-plane and out-of-plane orientation and show the impact on both Hall conductivities.

[1] A.H. MacDonald *et al.*, Phys. Rev. Lett., **112**, 017205 (2014)
[2] S. Nakatsuji *et al.*, Nature, **527**, 212-215 (2015)

MA 55.2 Thu 15:15 POT 6

Topological Hall signatures of electrons in magnetic hopfions — •Börge Göbel[1,2], Collins Akosa[3,4], Gen Tatara[3,5], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [3]RIKEN Center for Emergent Matter Science (CEMS), Hirosawa, Wako, Saitama, Japan — [4]Department of Theoretical and Applied Physics, African University of Science and Technology (AUST), Galadimawa, Abuja F.C.T, Nigeria — [5]RIKEN Center for Pioneering Research (CPR), Hirosawa, Wako, Saitama, Japan

Magnetic hopfions are topologically protected three-dimensional solitons that are constituted by a tube which exhibits a topologically non-trivial spin texture in the cross-section profile and is closed to a torus. We show that the topological Hall effect of electrons in such spin textures vanishes on the global level. However, in a local measurement, where the hopfion is located asymmetrically between two leads, a purely topological Hall signature arises due to the locally uncompensated emergent field. This fundamental effect can be exploited to electrically detect hopfions in experiments and to distinguish them from skyrmion tubes. Furthermore, it can potentially be utilized in spintronic devices. We propose a hopfion-based racetrack storage device and discuss switching of currents by tilting the stabilizing magnetic field.

MA 55.3 Thu 15:30 POT 6

Manipulation of the helical phase of chiral magnets with spin-transfer torque — •Jan Masell and Naoto Nagaosa — Center for Emergent Matter Science RIKEN, Wako, Saitama, Japan

The small Dzyaloshinskii-Moriya interaction in chiral magnets can lead to long-range modulations of the magnetization which can stabilize skyrmion lattices or a helical phase. While skyrmion lattices are well-known to be highly mobile and manipulable by electric currents, the helical phase is often strongly pinned. In thin films of chiral magnets, however, the current density can be large enough to depin the helix. We study the dynamics of the helical phase under spin transfer torques by combining analytics and numerical simulations of the micromagnetic model, and reveal how a reorientation of the helical phase can be achieved and exploited for memory devices.

MA 55.4 Thu 15:45 POT 6

Non-local symmetry breaking effects, induced by magnetostatics in curvilinear ferromagnetic shells — Denis D. Sheka[1], •Oleksandr V. Pylypovskyi[1,2], Pedro Landeros[3], Yuri Gaididei[4], Attila Kákay[2], and Denys Makarov[2] — [1]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine — [2]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [3]Universidad Técnica Federico Santa María, Avenida España Valparaíso, Chile — [4]Institute for Theoretical Physics, Kyiv, Ukraine

We present a micromagnetic theory of curvilinear ferromagnetic shells [1]. We show the appearance of new chiral effects, originating from the magnetostatic interaction. They manifest themselves even in statics and are essentially nonlocal. This is in contrast to conventional Dzyaloshinskii–Moriya interaction (material intrinsic or curvature-induced, stemming from the exchange). The physical origin is in a non-zero mean curvature of a shell and non-equivalence between the top and bottom surfaces of the shell. To describe the new effects, we split a conventional volume magnetostatic charge into two terms: (i) magnetostatic charge, governed by the tangent to the sample's surface, and (ii) geometrical charge, given by the normal component of magnetization and the mean curvature. We classify the interplay between the symmetry of the shell, its local curvature and magnetic textures and apply the proposed formalism to analyse magnetic textures in corrugated shells with perpendicular anisotropy.

[1] D. D. Sheka et al. arXiv:1904.02641

15 min. break.

MA 55.5 Thu 16:15 POT 6

Magnetic Domain States in Synthetic Antiferromagnets with Perpendicular Magnetic Anisotropy — •Ruslan Salikhov[1], Fabian Samad[1], Benny Böhm[2], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Chemnitz University of Technology, Chemnitz, Germany

Magnetic multilayers (MLs) with perpendicular magnetic anisotropy (PMA), such as Co/Pt or Co/Pd, are the host materials for a variety of magnetic domain structures, e.g. aligned or labyrinth stripe domains, bubble domains and their mixtures [1]. Interleaving the Co/Pt (or Co/Pd) blocks by Ru or Ir layers tuned to promote antiferromagnetic (AF) interlayer coupling between adjacent PMA ML blocks, results in synthetic antiferromagnets (SAFs) with PMA [2]. The AF interlayer exchange energy alters the typical energy balance and is the source of newly evolving metamagnetic domain states in the corresponding magnetic-phase diagram [3]. Here we demonstrate the stabilisation of metamagnetic bubble domains in the $[Co/Pt]_8Co/Ru_{18}$ SAFs at zero fields and ambient temperature.

[1] K. Chesnel, et al., Phys. Rev. B 98 224404 (2018) [2] O. Hellwig, et al., JMMM 319, 13-55 (2007) [3] N. S. Kiselev, et al., Phys. Rev. B 81, 054409 (2010)

MA 55.6 Thu 16:30 POT 6

Domain formation and domain wall motion in synthetic antiferromagnets controlled by focused ion beam irradiation — •Fabian Samad[1,2], Leopold Koch[2], Gregor Hlawacek[1], Sri Sai Phani Kanth Arekapudi[2], Miriam Lenz[1], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Chemnitz University of Technology, Chemnitz, Germany

By tuning the energy landscape of layered synthetic antiferromagnets (SAFs) with perpendicular anisotropy, a great variety of magnetic phases can be stabilized, as was shown previously by changing the layer thicknesses and repetition numbers [1]. Here, in contrast, we use focused He+ ion beam irradiation in order to controllably and locally change the energy balance, giving rise to laterally coexisting magnetic textures. Using intermediate He+ ion fluences, we achieve a phase transition to ferromagnetic stripe domains. For low He+ ion fluences, an antiferromagnetic (AF) remanent domain is nucleated, stabilized with an inverse magnetization structure as compared to the naturally preferred non-irradiated AF remanent state, thus allowing us to write well defined AF domains on the nanoscale into our SAF system. When exposed to an external out-of-plane magnetic field, structures irradiated with a fluence gradient exhibit a continuous domain annihilation from the high to the low fluence region. This could be utilized for engineering a controllable and local stray field landscape within the stray field free environment provided by the as prepared SAF ground state. [1] Hellwig et al., J. Magn. Magn. Mater. 319, 13-55 (2007).

MA 55.7 Thu 16:45 POT 6

Few-nm tracking of vortex orbits in the presence of disorder using Ultrafast Lorentz Microscopy — •Marcel Möller, John H. Gaida, Sascha Schäfer und Claus Ropers — 4th Physical Institut, Goettingen, Germany

Static Lorentz Transmission Electron Microscopy presents itself as a viable method for the mapping of nanoscale magnetic textures, offering a resolution down to one nanometer. In this contribution, we demonstrate its adaptation to time-resolved imaging, offering fascinating prospects for studying ultrafast magnetization dynamics. The Göttingen Ultrafast Transmission Electron Microscope (UTEM) is a newly developed instrument, which allows for studies of ultrafast magnetization and demagnetization dynamics induced by radio-frequency currents or optical pulses. This is facilitated with an electron source which can deliver electron pulses with a duration down to 200 fs.

Here, we focus on the investigation of the gyrotropic motion of a magnetic vortex confined within a 26 nm thick 2.1μm x 2.1μm permalloy nanoisland [1]. We demonstrate that we can track the vortex core position with an accuracy below 5 nm, measured by the deviation form an ideal elliptical trajectory and the deviation between identical acquisitions, respectively. Furthermore, using a sinusoidal current pulse which only lasts for a cycles, we can trace the build-up and relaxation of the vortex gyration, which reveals a temporal hardening of the free oscillation frequency and an increasing orbital decay rate attributed to local disorder in the vortex potential.

[1] M. Möller, et al., arXiv:1907.04608 (2019)

MA 55.8 Thu 17:00 POT 6

Unidirectionally tilted domain walls in chiral biaxial stripes — •Oleksandr V. Pylypovskyi[1,2], Volodymyr P. Kravchuk[3], Oleksii M. Volkov[1], Jürgen Fassbender[1], Denis D. Sheka[2], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine — [3]Karlsruher Institut für Technologie

The orientation of a chiral magnetic domain wall in a racetrack determines its dynamical properties. In equilibrium, magnetic domain walls are expected to be oriented perpendicular to the stripe axis. We demonstrate the appearance of a unidirectional domain wall tilt in an out-of-plane magnetized stripes with biaxial anisotropy (the firsrt easy axis is perpendicular to the plane and the second one is tilted with respect to the stripe axis) and interfacial Dzyaloshinskii–Moriya interaction (DMI). The tilt is a result of the interplay between the in-plane easy-axis anisotropy and DMI. We show that the additional anisotropy and DMI prefer different domain wall structure: anisotropy links the magnetization azimuthal angle inside the domain wall with the stripe main axis in contrast to DMI, which prefers the magnetization perpendicular to the domain wall plane. Their balance with the energy gain due to domain wall extension defines the equilibrium magnetization and domain wall tilt angles. We demonstrate that the Walker field and the corresponding Walker velocity of the domain wall can be enhanced in the system supporting tilted walls.

MA 56: Surface Magnetism I (joint session O/MA)

Time: Thursday 15:00–18:00 Location: WIL A317

MA 56.1 Thu 15:00 WIL A317

Magnetic properties of multilayer vanadyl phthalocyanine on Pb(111) — •Piotr Kot, Maximillian Uhl, Robert Drost, and Christian R. Ast — Max Planck Insitute for Solid State Research

Single-molecule magnets have been of great interest to the condensed matter community due to their potential applications in memory storage and quantum computing [1], and their inherent usefulness in studying fundamental quantum mechanics [2]. Here we present a study of vanadyl phthalocyanine (VOPc) molecules which, when deposited in the correct conditions, form multilayer nano-crystals on the surface of Pb(111) with two possible molecular orientations at each layer. Only one of the VOPc orientations on the first layer shows a spin excitation with energy splitting consistent with a spin half system, which agrees with recent findings [3]. The magnetic properties found on the second layer of molecules is also only observed in one of the molecular orientations, and shows strong zero-field splitting. This suggests that the way the first and second layer molecules interact with their environments varies significantly.

1. Leuenberger, Michael N., and Daniel Loss. "Quantum computing in molecular magnets." *Nature* 410.6830 (2001): 789.
2. Gatteschi, Dante, and Roberta Sessoli. "Quantum tunneling of magnetization and related phenomena in molecular materials." *Angewandte Chemie International Edition* 42.3 (2003): 268-297.
3. Malavolti, Luigi, et al. "Tunable Spin*Superconductor Coupling of Spin 1/2 Vanadyl Phthalocyanine Molecules." *Nano letters* 18.12 (2018): 7955-7961.

MA 56.2 Thu 15:15 WIL A317

Influence of the Molecular Arrangement on the Magnetic Properties of FePc and $FePcF_{16}$ thin films — •Katharina Greulich[1], Axel Belser[1], Sven Bölke[1], Reimer Karstens[1], Peter Nagel[2], Stefan Schuppler[2], Michael Merz[2], Thomas Chassé[1], and Heiko Peisert[1] — [1]Institute of Physical and Theoretical Chemistry, University of Tübingen — [2]Institute for Solid-State Physics, Karlsruhe Institute of Technology

The electronic configuration and thus the magnetic properties of the central metal atom of some transition metal phthalocyanines are not fully understood and have been intensely debated over the last years. A particularly broad complexity of the electronic structure is expected for Fe(II) phthalocyanines and porphyrins. In our XPS, XAS and XMCD studies, we compare thin films of FePc with their perfluorinated counterpart $FePcF_{16}$. The results indicate that the magnetic and electronic properties of the central Fe atom depend distinctly on the arrangement of the molecules in thin films. Compared to $FePcF_{16}$, FePc shows an unusually large XMCD signal at the Fe $L_{3,2}$-edge pointing to collective magnetic properties that do not seem possible in $FePcF_{16}$ due to a different molecular arrangement.

MA 56.3 Thu 15:30 WIL A317

Kondo effect of a singly occupied molecular orbital in bis(phthalocyaninato)-dysprosium double decker molecules — •Timo Frauhammer[1], Timofey Balashov[1,2], Gabriel Derenbach[1], Svetlana Klyatskaya[3], Eufemio Moreno-Pineda[3], Mario Ruben[3], and Wulf Wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Germany — [2]II. Physikalisches Institut, RWTH Aachen, Germany — [3]Institute of Nanotechnology, Karlsruhe Institute of Technology, Germany

Double decker bis(phthalocyaninato)-dysprosium single molecule magnets adsorbed on Au(111) have been investigated using low temperature STM. No direct magnetic signal by the 4f electrons could be detected in STS. However, a clear Kondo resonance located on the ligands of the molecules can be observed. This indicates an odd number of electrons residing in the molecular orbitals of the ligands. Interestingly, a splitting of this Kondo resonance has been observed even in the absence of external magnetic fields, which can be attributed to a ferromagnetic exchange coupling between the unpaired spin on the ligands and the 4f angular momentum of the Dy central ion. Using spin-polarized tips, this might enable the readout of the 4f spin of Dy.

MA 56.4 Thu 15:45 WIL A317

Real-time susceptibility measurements of CoTMPP on magnetic Ni/Cu(110)-(2x1)O thin films — •Gizem Mendirek[1], Aleksander Brozyniak[1], Michael Hohage[1], Mariella Denk[1], Andrea Navarro-Quezada[1,2], and Peter Zeppenfeld[1] — [1]Institut für Experimentalphysik, Johannes Kepler Universität Linz, Altenberger Str. 69, 4040 Linz, Österreich — [2]Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität Linz, Altenberger Str. 69, 4040 Linz, Österreich

The magneto-optic signal of organic molecular thin films is expected to be rather small. Therefore, a high sensitivity is required to measure the magnetic susceptibility of thin molecular layers. In this work we present the implementation of a sinusoidal modulation of the magnetic field to a Reflectance Difference Magneto-Optical Kerr Effect (RD-MOKE) setup with increased sensitivity that allows detecting of variations of the Kerr rotation angle below 1 μrad/mT at applied fields of a few mT. We illustrate the capabilities of the setup for Ni thin films grown on Cu(110)-(2x1)O surfaces, which exhibit a sharp spin reorientation transition (SRT) of the magnetic easy axis from in-plane to out-of-plane at a coverage of 9 ML. Subsequent deposition of cobalt tetramethoxyphenylporphyrin (CoTMPP) on Ni/Cu(110)-(2x1)O surface induces characteristic changes in the magnetic properties that can be monitored in real-time during the growth of the organic layer. Our results demonstrate the potential of the setup for studying ultrathin organic/ferromagnetic interfaces.

MA 56.5 Thu 16:00 WIL A317

Emergence of on-surface molecular magnetism by non-magnetic impurity doping — •Roberto Robles[1], We-Hyo Soe[2], Carlos Manzano[3], Nicolás Lorente[1,4], and Christian Joachim[2] — [1]Centro de Física de Materiales CFM/MPC (CSIC-UPV/EHU), San Sebastián, Spain — [2]Centre d'Elaboration de Matériaux et d'Études Structurales (CEMES), CNRS, Université de Toulouse, Toulouse, France — [3]Institute of Material Research and Engineering (IMRE), Agency for Science, Technology and Engineering (A*STAR), Singapore — [4]Donostia International Physics Center (DIPC), San Sebastián, Spain

Using a low-temperature scanning tunneling microscope (LT-STM) combined with density functional theory (DFT) calculations we show how non-magnetic organic molecules on a metallic surface can become magnetic by doping them with light metal atoms. By single atom/molecule manipulation we construct a complex formed by two aluminum atoms doping a phenanthrazine molecule on an Au(111) surface. We use the Kondo effect to characterize the magnetic moment and confirm the emergence of a localized magnetic moment in the 2(Al)-phenanthrazine complex. DFT calculations allow us to describe the electronic and magnetic properties of the new system. This procedure opens a new way to design light magnetic molecular complexes without the need of transition metal atoms.

MA 56.6 Thu 16:15 WIL A317

Probing intramolecular metal-ligand spin coupling by STM — •yuqi wang[1], soroush arabi[1], klaus kern[1,2], and markus ternes[3,4] — [1]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [2]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland — [3]RWTH Aachen University, Institute of Physics, D-52074 Aachen, Germany — [4]Peter-Grünberg-Institute, Forschungszentrum Jülich, D-52425 Jülich, Germany

The bonding of metal-organic molecules to a substrate induces molecular ligand spin states, which lead to an intramolecular conductance and spin dynamics [1]. However, the intramolecular spin coupling has not been studied in detail at molecular scale yet. Here we use a low-temperature scanning tunneling microscope (STM) to study cobalt phthalocyanine (CoPc) molecules on a 2H-$NbSe_2$ substrate. We observe that there are two kinds of adsorbed CoPc molecules due to two slightly different adsorption geometries. While one behaves like a S = 1/2 system which introduces Yu-Shiba-Rusinov states in the superconducting gap of the substrate [2], the other behaves like an effective S = 0 system which shows a singlet-triplet transition at about 23 meV due to the antiferromagnetic coupling between the central Co atom of the metal-organic complex and its ligands. [1] A. Mugarza, *et al., Nat. Comm.* **2**, 490 (2011). [2] S. Kezilebieke, *et al., Nano Lett.* **18**, 2311 (2018).

MA 56.7 Thu 16:30 WIL A317

Mapping magnetic anisotropies in molecular junctions — •Cristina Mier[1], Leonard Garnier[2], Benjamin Verlhac[2], Roberto Robles[1], Laurent Limot[2], Nicolás Lorente[1], and Deung-Jang Choi[1] — [1]Centro de Física de Materiales (MPC) CSIC-EHU, San Sebastián, Spain — [2]Université de Strasbourg, CNRS, IPCMS, UMR 7504, Strasbourg, France

The ability to control the spin of single molecules is of great interest for the development of quantum technologies. Nickelocene ((Ni(C_5H_5)$_2$,NiCp_2) is a magnetic molecule with spin S=1, which shows a big electronic inelastic signal due to the excitation of its spin state [1]. We studied this molecule on a superconducting surface and used a superconducting tip which allows us having a higher energy resolution than the one with normal metallic tips. We found peaks in the differential conductance due to the spin excitations, permitting us to determine the magnetic anisotropy energy (MAE) of the system. The energy position of peaks is slightly shifted at different molecules, which indicates differences in magnetic anisotropy energies for each molecules. This study gives us more parameters to tune the MAE in a molecular junction.

[1] M. Ormaza, N. Bachellier, M. N. Faraggi, B. Verlhac, P. Abufager, P. Ohresser, L. Joly, M. Romeo, F. Scheurer, M.-L. Bocquet, N. Lorente, and L. Limot. Efficient spin-flip exci- tation of a nickelocene molecule. Nano Letters, 17(3):1877*1882, 2017. PMID: 28199115.

MA 56.8 Thu 16:45 WIL A317

Organic radical functionalisation of a gold surface — •Tobias Junghöfer, Ewa Malgorzata Nowik-Boltyk, and Maria Benedetta Casu — Eberhard Karls Universität Tübingen, Institut für Physikalische und Theoretische Chemie, 72076 Tübingen, Germany

Organic radical thin films are of great interest for organic electronics such as spin filtering devices, data storage devices, and as quantum bits for quantum computing devices. Here we present the functionalisation of a gold substrate by using a derivative of the perchlorotriphenylmethyl (PTM) radical. PTM is a very chemically and thermally stable radical. We investigate the gold/PTM derivative interface by using soft X-ray techniques, such as X-ray photoelectron spectroscopy (XPS) and near-edge X-ray absorption fine structure (NEXAFS) spectroscopy. Our results show that the functionalisation is successful under specific preparation conditions. The radical is still intact and keeps its magnetic character at the interface. Our findings are a significant step forward on the implementation of organic radicals in molecular-based devices with different properties and applications as energy, sensing, imaging, memories, and spintronics.

MA 56.9 Thu 17:00 WIL A317

Spin-polarized photoelectron emission from chiral cupric oxide layers — •Paul Möllers[1], Daniel Nürenberg[1], Koyel Banerjee Ghosh[2], Wenyan Zhang[2], Francesco Tassinari[2], Yitzhak Mastai[2], Ortal Lidor-Shalev[2], Simon Wei[3], Emil Wierzbinski[3], David Waldeck[3], Ron Naaman[2], and Helmut Zacharias[1] — [1]Center for Soft Nanoscience, Westfälische Wilhelms-Universität, 48149 Münster, Germany — [2]Department of Chemical and Biological Physics, Weizmann Institute of Science, 76100 Rehovot, Israel — [3]Chemistry Department, University of Pittsburgh, Pittsburgh, PA 15260, United States

The chirality-induced spin selectivity (CISS) effect introduces a coupling between the linear and the spin angular momentum of electrons moving through a chiral molecule [1]. Chiral cupric oxide (CuO) layers can be grown by electrodeposition from a solution containing chiral precursor molecules such as tartaric acid [2]. The choice of the enantiomer of this precursor determines the chiral crystal structure and the preferential crystallographic orientation.

Here, we present results from spin-resolved photoemission experiments performed with chiral CuO layers to investigate the presence of CISS. We demonstrate that the spin polarization observed in these layers can be exploited to enhance the chemical selectivity of an electrocatalytic water splitting reaction [3].

[1] R. Naaman et al., Nat Rev Chem 3, 250 (2019) [2] Kothari et al., Chem. Mater. 16, 4232 (2004) [3] K. B Gosh et al., J. Phys. Chem. C 123, 3024 (2019)

MA 56.10 Thu 17:15 WIL A317

Quantifying exchange forces of a spin spiral on the atomic scale — Nadine Hauptmann[1], Soumyajyoti Haldar[2], Tzu-Chao Hung[1], •Wouter Jolie[1], Lorena Niggli[1,3], Mara Gutzeit[2], Daniel Wegner[1], Stefan Heinze[2], and Alexander A. Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität, Kiel, Germany — [3]Physik Institut, University of Zurich, Switzerland

Chiral magnetic structures are stabilized by an interplay between competing exchange interactions at the atomic scale. Spin-polarized scanning tunneling microscopy (SP-STM) has achieved great success in investigating the magnetization of such structures, but faces a number of limitations in being able to directly detect the underlying exchange forces, as well as delineate between structural and electronic contributions. To go beyond these limitations, we have developed a new method, which combines SP-STM and magnetic exchange force microscopy (SPEX) based on nc-AFM. Here, we utilize SPEX to investigate a monolayer of Mn on W(110), which exhibits an antiferromagnetic cycloidal spin-spiral ground state driven by the Dzyaloshinskii-Moriya interaction. We show that our force measurements are more sensitive to atomic-scale variations of the exchange force field and the local chemical environment than the current [1]. First-principles calculations explain our observations and reveal the magnetic exchange force mechanisms.

[1] N. Hauptmann et al., arXiv:1908.00959

MA 56.11 Thu 17:30 WIL A317

Magnetism of valence electrons in lanthanide atoms on metallic substrates and lanthanide thin films — •Daria Sostina[1,2], Aparajita Singha[1,2], Christoph Wolf[1,2], Safa Ahmed[1,2], Denis Krylov[1,2], Pierluigi Gargiani[3], Alessandro Barla[4], Woosuk Noh[5], Marina Pivetta[6], Stefano Rusponi[6], Harald Brune[6], Andreas Heinrich[1,2], and Fabio Donati[1,2] — [1]Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul, Republic of Korea — [2]Department of Physics, Ewha Womans University, Seoul, Republic of Korea — [3]ALBA Synchrotron Light Source, Cerdanyola del Vallès, Catalonia, Spain — [4]Istituto di Struttura della Materia (ISM), Consiglio Nazionale delle Ricerche (CNR), Trieste, Italy — [5]Pohang University of Science and Technology, Pohang, Republic of Korea — [6]Institute of Physics, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Valence electrons in rare earth single atoms play a fundamental role in determining their magnetic stability and energy level structure [Phys. Rev. Lett. 121, 027201 (2018)]. Here, we investigate the occupation and magnetic moments of 5d and 6p electrons of Gd in the metallic state using X-ray magnetic circular dichroism. We observe charge transfer to occur when Gd atoms and clusters are deposited on Ag(100) surface and negligible occupation of Gd 5d orbital. Additional measurements performed on Gd films and related comparison with density functional theory allow us to understand the contribution of electron-electron correlations and hybridization of the Gd 5d orbitals to the magnetism of rare earths atomic-scale structures.

MA 56.12 Thu 17:45 WIL A317

Magnetism of surface-embedded lanthanide single atoms with room temperature structural stability — •Safa Lamia Ahmed[1,2], Aparajita Singha[1], Denis Krylov[1], Stefano Rusponi[3], Marina Pivetta[3], Christoph Wolf[1], Alessandro Lodesani[4], Andrea Picone[4], Alberto Brambilla[4], Alessandro Barla[5], Harald Brune[3], Andreas Joachim Heinrich[1,2], and Fabio Donati[1,2] — [1]Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul 03760, Republic of Korea — [2]Department of Physics, Ewha Womans University, Seoul 03760, Republic of Korea — [3]Institute of Physics, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [4]Dipartimento di Fisica, Politecnico di Milano, 20133 Milano, Italy — [5]Istituto di Struttura della Materia (ISM), Consiglio Nazionale delle Ricerche (CNR), I-34149 Trieste, Italy

We investigate surface embedded lanthanide atoms in ultra-thin MgO film on Ag(100) as a potential solution towards realizing single atom magnets [Science 352, 318 (2016)] with room-temperature (RT) structural stability. RT scanning tunneling microscopy images show negligible surface diffusion and nucleation of the embedded atoms. Using X-ray magnetic circular dichroism, we reveal out-of-plane anisotropy for Tm and Sm; in-plane anisotropy for Ho and Dy and negligible anisotropy for Er and Gd. All systems show paramagnetic loops at 2.5 K. Using density functional theory and multiplet calculations, we model the interaction between the 4f electrons and their ligand environment, and determine the atom's magnetic level structure.

MA 57: Posters Magnetism II

Time: Thursday 15:00–18:00 Location: P3

MA 57.1 Thu 15:00 P3

Entropy estimation in high-throughput calculations — •Rafael Vieira[1], Olle Eriksson[1], Torbjörn Björkman[2], and Heike C. Herper[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Physics, Faculty of Science and Engineering, Åbo Akademi, FI-20500 Turku, Finland

The increasing interest in the application of magnetocaloric materials for magnetic cooling devices has led to an intensive search for new materials with a more attractive performance to cost ratio. High-throughput studies based on first-principles calculations can play a crucial role to detect new magnetocaloric materials and help to estimate trends for material tuning. To identify systems of interest in a large body of data, screening parameters are required and must be carefully chosen considering a balance between accuracy and cost of the calculations.

A key quantity to characterize the performance of these systems is the entropy variation between two magnetic phases. To estimate this quantity in a cost-efficient but accurate way, we test several approaches taking FeRh as a test system. A model for a first-principles estimation of the entropy variation between magnetic phases is proposed, considering three distinct and independent entropy contributions: electronic, lattice, and magnetic. Estimated values are presented, and the model applicability for computing the entropy variation as a screening parameter for magnetocaloric performance is discussed.

MA 57.2 Thu 15:00 P3

Advanced characterization of magnetocaloric materials in pulsed magnetic fields — •T. Gottschall[1], E. Bykov[1,2], C. Salazar Mejía[1], Y. Skourski[1], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

The direct determination of the adiabatic temperature change as a function of magnetic field and starting temperature is of central importance for a profound characterization of magnetocaloric materials. Recently, a technique was developed to measure the temperature change in pulsed magnetic fields by using ultra-thin thermocouples attached to the sample. In this work, we give an overview of the most recent results that have been obtained in pulsed fields at the Dresden High Magnetic Field Laboratory.

This work was supported by HLD at HZDR, member of the European Magnetic Field Laboratory (EMFL) and the Helmholtz Association via the Helmholtz-RSF Joint Research Group Project No. HRSF-0045.

MA 57.3 Thu 15:00 P3

Magnetocaloric effect in $DyCo_2$ and $Ho_{0.5}Dy_{0.5}Al_2$ rare-earth compounds — •E. Bykov[1,2], T. Gottschall[1], A. Karpenkov[3], K. Skokov[4], S. Taskaev[5,6,7], Y. Skourski[1], and J. Wosnitza[1,2] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Faculty of Physics, Tver State University, Russia — [4]Institute of Material Science, TU Darmstadt, Germany — [5]Departament of Physics, Chelyabinsk State University, Russia — [6]National University of Science and Technology MISiS, Russia — [7]National Research South Ural State University, Russia

Two of the most promising materials for magnetic gas liquefaction are the rare-earth compounds of the type RCo_2 and RAl_2, which have the so-called Laves phase crystal structure, in which the ferri- or ferromagnetic order appears at low temperatures [1]. In this work, we will present our recent results on the magnetocaloric effect of $DyCo_2$ and $Ho_{0.5}Dy_{0.5}Al_2$ in pulsed magnetic fields. Both compounds demonstrate large adiabatic temperature changes over a wide temperature window near their Curie temperatures (143 K for $DyCo_2$ and 44 K for $Ho_{0.5}Dy_{0.5}Al_2$). Especially the usage of $Ho_{0.5}Dy_{0.5}Al_2$ is interesting for a final stage of H_2 liquefaction in magnetic refrigerator devices. This work was supported by the Helmholtz Association via the Helmholtz-RSF Joint Research Group Project No. HRSF-0045.

[1] A. Kitanovski et. al, Int. J. Refrig. **57**, 288 (2015)

MA 57.4 Thu 15:00 P3

Multiscale modeling of magnon-phonon dynamics — •Pablo Nieves[1], Sergiu Arapan[1], Domink Legut[1], David Serantes[3], and Oksana Chubykalo-Fesenko[2] — [1]IT4Innovations, VŠB, Ostrava, Czech Republic — [2]Instituto de Ciencias de Materiales de Madrid, Madrid, Spain — [3]Universidade de Santiago de Compostela, Santiago de Compostela, Spain

Magnon-phonon scattering processes play an essential role in novel magnetic phenomena. Typically, the influence of temperature on the magnetization dynamics is studied. However, there is an inverse effect when the magnetization dynamics produces temperature change, for example in the magnetocaloric effect or during the heating under an ac applied magnetic field. Promising applications like magnetic refrigeration or magnetic hyperthermia treatment for cancer are based on these processes. Recently, we have developed a self-consistent micromagnetic approach to describe both magnetization and phonon temperature dynamics. The approach consists in the simultaneous solution of the quantum Landau-Lifshitz-Bloch micromagnetic equation coupled to the equation for the phonon temperature dynamics. The latter equation is derived from the self-consistent quantum mechanical treatment of the spin-phonon Hamiltonian, which includes direct transformation and Raman processes, based on the general theory for a spin system interacting weakly with a thermal bath. We discuss the main features of this novel micromagnetic approach, possible applications and its deep connection to spin-lattice simulations within a coarse-grained multiscale approach.

MA 57.5 Thu 15:00 P3

Charge and spin transport in $NiFe_2O_4$ thin films with varying lattice parameters — •Oliver Ritter, Jan Biedinger, Karsten Rott, and Timo Kuschel — Center for Spineletronic Materials and Devices, Bielefeld University, Germany

Nickel ferrite (NFO) as a ferrimagnetic insulator is a promising material for spin caloric applications [1]. In this work, twin samples of 45 nm NFO thin films have been prepared by sputter deposition on $MgAl_2O_4$ substrates and in-situ post annealed at different temperatures, thus modifying the lattice parameters of NFO. Subsequently, only one of each sample pair has been capped by 3 nm Pt for spin Seebeck effect studies. After standard structural and magnetic characterization of the samples, the electrical resistivity has been measured to identify the oxygen content [2,3]. The influence of the lattice parameters on thermally induced spin current transport has not been investigated so far, but will be discussed within this contribution.

[1] D. Meier et al., Phys. Rev. B 87, 054421 (2013)
[2] P. Bougiatioti, et al., Phys. Rev. Lett. 119, 227205 (2017)
[3] P. Bougiatioti, et al., J. App. Phys. 122, 225101 (2017)

MA 57.6 Thu 15:00 P3

Thermally generated spin transport in Fe_3O_4/NiO/Pt trilayers — •Johannes Demir[1], Stefan Becker[1], Lennart Schwan[2], Olga Kuschel[3], Joachim Wollschläger[3], and Timo Kuschel[1] — [1]Center for Spineletronic Materials and Devices, Bielefeld University, Germany — [2]Bielefeld Institute for Applied Materials Research (BIfAM), Bielefeld University of Applied Sciences, Department of Engineering Sciences and Mathematics, Germany — [3]Center of Physics and Chemistry of New Materials, Osnabrück University, Germany

We investigate the spin Seebeck effect (SSE) in Fe_3O_4/NiO/Pt trilayers by varying the thickness of the antiferromagnetic NiO layer from 0 to 20 nm. Furthermore, we compare the normalization of the SSE voltage to the temperature difference as well as to the experimentally detected heat flux [1]. The Fe_3O_4/NiO bilayer is grown in situ by molecular-beam epitaxy, while the Pt layer is deposited ex situ by DC sputtering. We discuss a possible enhancement of the spin-current signal in 1 nm NiO on 48 nm and 22 nm Fe_3O_4 for the temperature difference (as reported in literature [2]) as well as for the heat flux method. Additionally, we simulate the temperature gradient in Fe_3O_4 in an equivalent circuit model depending on the NiO thermal conductivity and the interface thermal conductances to examine the influence of the thermal depth profile of the NiO layer on the thermally induced spin current.

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

MA 57.7 Thu 15:00 P3

Influence of post annealing on structural, magnetic and electric properties of sputter-deposited $NiFe_2O_4$ thin films — •Jan Biedinger, Luca Marnitz, Karsten Rott, and Timo Kuschel — Center for Spineletronic Materials and Devices, Bielefeld University, Germany

In the presented work, the structural, magnetic and electric properties of $NiFe_2O_4$ (NFO) thin films treated by post annealing in pure oxygen atmosphere have been studied. Therefore, NFO films (45 nm) were prepared via reactive dc magnetron co-sputtering on $MgAl_2O_4$ substrates [1] and post annealed in-situ with temperatures ranging from 350°C to 700°C. Each sample was subsequently characterized by ex-situ means of x-ray fluorescence, x-ray reflectivity, x-ray diffraction and alternating gradient magnetometry. Additionally, resistivity measurements have been performed to investigate the oxygen content of the NFO films [2,3]. The ferrimagnetic insulating characteristic was identified for all treated samples. According to the structural analysis, the out-of-plane lattice constant decreased by increasing the annealing temperature, indicating more bulk-like structural properties, whereas the film roughness rose for the highest temperature of 700°C. In a next step, these films will be used for thermally induced spin transport experiments.

[1] C. Klewe et al., J. Appl. Phys. 115, 123903 (2014).
[2] P. Bougiatioti et al., J. Appl. Phys. 122, 225101 (2017).
[3] P. Bougiatioti et al., Phys. Rev. Lett. 119, 227205 (2017).

MA 57.8 Thu 15:00 P3

Spin Seebeck effect in $NiFe_2O_4$ thin films deposited on differently doped Nb:$SrTiO_3$(001) substrates — •Tobias Peters[1], Oliver Ritter[1], Jannis Thien[2], Jari Rodewald[2], Joachim Wollschläger[2], Ronja Heinen[3], Martina Müller[3,4], and Timo Kuschel[1] — [1]Center for Spinelectronic Materials and Devices, University of Bielefeld, Germany — [2]Center of Physics and Chemistry of New Materials, Osnabrück University, Germany — [3]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [4]Technical University of Dortmund, Germany

We investigated the spin Seebeck effect (SSE) in Pt/$NiFe_2O_4$ bilayers grown on differently doped Nb:$SrTiO_3$(001) (STO) substrates and studied the influence of deposition techniques. The nickel ferrite (NFO) has been deposited in thicknesses of 30nm via magnetron sputtering[1], molecular beam epitaxy[2] and pulsed laser deposition[3] on STO substrates with Nb content of 0%, 0.05% and 0.5%. SSE measurements have been performed, based on the normalization of the SSE driven electrical field in the Pt to the applied heat flux instead to the temperature difference, to avoid uncertainties from varying thermal conductivities between sample and setup [1]. For the NFO films on doped STO substrates we found SSE magnitudes comparable to the SSE in NFO on MgO(001) independent of the deposition technique. Only differences in the signal-to-noise ratio could be connected to the choice of the substrate.

[1] A. Sola et al., Sci. Rep. 7, 46752 (2017)

MA 57.9 Thu 15:00 P3

Towards spin-polarized scanning tunneling spectroscopy of exfoliated 2D magnets — •Benjamin Pestka[1], Jeff Strasdas[1], Matthew Hamer[2], Astrid Weston[2], Adam Budniak[3], Efrat Lifshitz[3], Yaron Amouyal[3], Roman Gorbachev[2], and Markus Morgenstern[1] — [1]II. Institute of Physics B, RWTH Aachen University, Germany — [2]School of Physics and Astronomy, University of Manchester, UK — [3]Schulich Faculty of Chemistry, Department of Materials Engineering, Technion, Haifa 3200003, Israel

Magnetic properties of 2D van der Waals materials are of particular interest for studying magnetic nanoscale interactions. Among others, one has identified the 2D ferromagnets (FM) CrI3 and CrBr3 as well as the anti-ferromagnets (AFM) CrPS4 and MnPS3. Different magnetic couplings between layers due to stacking order have been found and switching by electric field between FM and AFM layer coupling has been demonstrated. Our study focuses on scanning tunneling microscopy (STM) of the FM semiconductor CrBr3 at 6 K and the exfoliation and transfer process of the AFM semiconductor CrPS4 as preparation for future STM investigations. For CrBr3 flakes exfoliated on HOPG in Ar-atmosphere followed by ultra-high-vacuum transfer to the STM, we show atomically resolved STM topography and spectroscopy measurements showcasing the band gap of CrBr3. First spin-polarized measurements with a Cr tip in varying magnetic fields are presented. For CrPS4, we employed different exfoliation processes on SiO2, HOPG and h-BN that led to thicknesses down to 4 layers as measured by atomic force microscopy and Raman spectroscopy.

MA 57.10 Thu 15:00 P3

Trends of higher-order exchange interactions in transition metal trilayers — •Mara Gutzeit, Soumyajyoti Haldar, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstrasse 15, 24098 Kiel, Germany

Higher-order exchange interactions (HOI) beyond the pair-wise Heisenberg exchange can play a crucial role in the formation of the magnetic ground state of a system. Prominent examples are both Rh/Fe atomic bilayers on Ir(111) [1] and a monolayer Fe on Rh(111) [2] which are shown to exhibit a double-row-wise antiferromagnetic ($\uparrow\uparrow\downarrow\downarrow$) ground state stabilized by HOI. Here, employing density functional theory as implemented in the FLEUR and VASP code, we investigate the behaviour of HOI in magnetic trilayer systems. Choosing the abovementioned Rh/Fe/Ir system as a starting point, we systematically study how the HOI change not only with the band filling as Rh (Ir) is replaced by other elements of the $4d$ ($5d$) series but also how they are affected by different stackings of the involved transition metals. Additionally, trends for HOI parameters are presented for the case that the central $3d$ element Fe is replaced by Co. Finally, the values obtained for the biquadratic exchange, the four-site-four-spin term and the three-site-four-spin interaction of the trilayers are compared with values calculated for respective ultrathin film systems.

[1] Romming *et al.* PRL 120, 207201 (2018)
[2] Krönlein *et al.* PRL 120, 207202 (2018)

MA 57.11 Thu 15:00 P3

Magnetism and spin dynamics in single-layer antiferromagnetic insulator $MnPS_3$ — •Martin Alliati[1], Richard F. L. Evans[2], and Elton J. G. Santos[1] — [1]School of Mathematics and Physics, Queen's University Belfast, BT7 1NN, UK — [2]Department of Physics, University of York, YO10 5DD, UK

Two-dimensional magnets have recently attracted considerable attention, both from a fundamental standpoint and in terms of their potential applications, e.g., the prospect of antiferromagnetic spintronics devices based on single-layer transition metal thiophosphates. In particular, the magnetic properties in $MnPS_3$ are intrinsically coupled to the crystal and electronic structures, and then can be affected by tunable parameters. This arises from an interplay between different electronic quantities that remains to be fully understood at the monolayer limit. Here we tackle this challenge through a multi-scale approach. First, ab-initio calculations were performed to understand the crystal and electronic structures of this material, as well as its magnetic properties such as easy-axis anisotropy and anisotropic exchange. Subsequently, nano-scale magnetic simulations were performed to unveil the effect of different perturbations on the magnetic ordering of this material through Monte Carlo methods and Landau-Lifshitz-Gilbert (LLG) dynamics. This includes a description of the magnetic domains at different temperatures, domain wall motion and ultrafast spin dynamics induced by pulsed magnetic fields. The results presented here broaden our understanding of single-layer $MnPS_3$, thus representing a step forward towards ultrathin antiferromagnetic spintronics.

MA 57.12 Thu 15:00 P3

Magnetoresistance effects in two-dimensional magnetic van der Waals systems — •Franziska Martin[1], Rui Wu[1], Romain Lebrun[1], Tanja Scholz[2], Jinbo Yang[3], Bettina Lotsch[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [2]Max Planck Institute for solid state research, 70569 Stuttgart — [3]School of Physics, Peking University, 100871, Beijing, China

Two-dimensional materials exhibiting a weak interlayer van der Waals bonding provide the opportunity for mechanical exfoliation down to single atomic layers. While non magnetic two-dimensional materials, like transition metal dichalcogenides, offer a broad range of electronic properties [1], combining magnetism with the confinement of two dimensions opens up the potential of effective current control of magnetization [2]. We focus on metallic as well as insulating ferromagnetic and antiferromagnetic two-dimensional van der Waals materials, for which we have previously determined the temperature dependence of the anisotropies [3]. We measure the spin Hall magnetoresistance [4] to probe magnetization and the Néel vector in these systems. References: [1] Manzeli et al., Nat. Rev. Mater. 2, 17033 (2017), [2] Mak et al., Nat. Rev. Phys. 1, 646 (2019), [3] N. Richter et al., Phys. Rev. Mater. 2, 024004 (2018), [4] Nakayama et al., Phys. Rev. Lett. 110, 206601 (2013)

MA 57.13 Thu 15:00 P3

Ab initio studies of magnetic interactions in $MnBi_2Te_4$ and related monolayers — •Donya Mazhjoo, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Novel 2D magnetic materials offer a versatile platform to study magnetism in two dimensions. Density functional theory (DFT) calculations can be used to find not only the ground statemagnetic structure but also to disentangle different magnetic interactions.Using the full-potential linearized augmented planewave method (FLAPW) as implemented in the Fleur-code [1], we investigate the magnetic properties of monolayers of $MnBi_2Te_4$, that is an antiferromagnetic topological insulator in the bulk [2] and compare to $MnBi_2Se_4$ and $MnSb_2Te_4$. We focus on the scalar exchange interaction energy and on spin-orbit coupling (SOC) effects like the magnetic anisotropy. Also, we explore the impact of the SOC on the exchange interaction energy and the magnetic ordering temperature of these materials.
[1] Ph. Kurz *et al.*, PRB 69, 024415 (2004).
[2] M. Otrokov *et al.*, arXiv:1809.07389(2018).

MA 57.14 Thu 15:00 P3

Hot carrier relaxation in two-dimensional materials — •Franz Fischer, Franziska Töpler, Nicki Frank Hinsche, Jürgen Henk, and Ingrid Mertig — Martin Luther University Halle-Wittenberg, Institute of Physics, 06099 Halle (Saale), Germany

Atomically thin layers of transition metal dichalcogenides attract remarkable interest due to their extraordinary electronic and optical properties. The lack of inversion symmetry in their crystal structure combined with strong spin-orbit interaction gives rise to an extra valley degree of freedom as well as large spin splittings in the Brillouin zone (BZ). The latter are accompanied by presumably large Berry curvature.

After gaining a net Berry curvature in the BZ by tuning the electronic band structure with electric and magnetic fields – which induce spatial and time symmetry breaking – we realized an anomalous Hall effect (AHE). We are developing a framework to study the time-dependent evolution of the AHE and other electronic transport properties in various 2D systems by solving time-dependent Boltzmann equation models. We aim to compare our results to those of theoretical and experimental many-temperature models to gain deeper insight into ultrafast carrier relaxation processes.

MA 57.15 Thu 15:00 P3

Relaxation behaviour of antiferromagnetic grains in polycrystalline exchange bias 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

The macroscopic magnetic characteristics of polycrystalline exchange bias thin films (antiferromagnet/ferromagnet) are mainly linked to the grain size distribution of the antiferromagnetic layer, which can be divided into classes of thermally unstable as well as thermally stable grains. These grain classes are connected to the coercivity and the horizontal shift (exchange bias field) of the ferromagnetic hysteresis loop, respectively. In order to tune the contribution of rotatable and pinning grains, sets of IrMn/NiFe and IrMn/CoFe bilayers with varying antiferromagnetic layer thickness were fabricated via sputter-deposition. Applying the first-order reversal curve (FORC) formalism, the distribution of coercivities and interaction fields of the granular systems have been determined complementary to angular-resolved hysteresis measurements using Kerr-magnetometry in comparison to an extended Stoner-Wohlfarth model. The combination allowed for the quantitative determination of material parameters and the deconvolution of grain class contributions. Additionally, by changing the sweep rate of the external magnetic field during a magnetization reversal process enabled the investigation of the relaxation times of the antiferromagnet's thermally unstable and therefore rotatable grains.

MA 57.16 Thu 15:00 P3

Tailoring of exchange bias in magnetic thin films via electrochemical transformation of the ferromagnetic layer — •Rico Huhnstock[1], Jonas Zehner[2], Steffen Oswald[2], Ivan Soldatov[2], Arno Ehresmann[1], Kornelius Nielsch[2], Dennis Holzinger[1], and Karin Leistner[2] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Leibniz Institute for Solid State and Materials Research Dresden, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden

In recent research targeted modification of the interface related Exchange Bias (EB) effect in magnetic thin film systems is considered to be a crucial factor in designing artificial magnetic stray field landscapes which can be employed in e.g. biomedical point-of-care diagnostics. In this regard, the challenge of tuning the EB in a reversible and nonvolatile manner opens up new opportunities with the application of magnetoionic approaches potentially playing a key role in overcoming present obstacles. Hence, in this work we demonstrate an electrochemical routine for the electric control of EB by a Redox transformation of the ferromagnetic layer in a Fe/IrMn based thin film system [1]. The influence of several experimental parameters on the here investigated tailoring of EB will be discussed alongside a route towards reversible control of EB. To conclude, an outlook on structuring EB systems magnetically with the presented technique will be given.
[1] Zehner *et al.* (2019), Adv. Electron. Mater., 5(6):1900296.

MA 57.17 Thu 15:00 P3

X-ray magnetic linear dichroism as a probe for non-collinear magnetic state in ferrimagnetic single layer exchange bias systems — •Chen Luo[1,2,3], Hanjo Ryll[1], Christian Back[2,3], and Florin Radu[1] — [1]Helmholtz-Zentrum-Berlin für Materialen und Energie, Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [2]Institute of Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany — [3]Institute of Experimental Physics of Functional Spin Systems, Technical University Munich, James-Franck-Str. 1, 85748 Garching b. München, Germany

Ferrimagnetic alloys are extensively studied for their unique magnetic properties leading to possible applications in perpendicular magnetic recording. On a prototype ferrimagnetic alloy we demonstrate fascinating properties that occur close to a critical temperature where the magnetization is vanishing, just as in an antiferromagnet. An anomalous 'wing shape' hysteresis loop is observed slightly above the compensation temperature. This bears the characteristics of an intrinsic exchange bias effect, referred to as atomic exchange bias. We further exploit the X-ray magnetic linear dichroism contrast for probing non-collinear states which allows us to discriminate between two main reversal mechanisms, namely perpendicular domain wall formation versus spin-flop transition. Ultimately, we analyze the elemental magnetic moments for the surface and the bulk parts, separately, which allows to identify in the phase diagram the temperature window where this effect takes place. Moreover, we suggests that this effect is a general phenomenon in ferrimagnetic thin films.

MA 57.18 Thu 15:00 P3

Investigation of Granular Magnetic Exchange Coupled Nano-Composites — Runbang Shao, Siming Zou, Nitish Jangale, Balati Kuerbanjiang, and •Ulrich Herr — Institut für Funktionelle Nanosysteme, Universität Ulm, Ulm, Deutschland

Exchange coupling of ferromagnetic (FM) nanoparticles (NPs) to antiferromagnets (AF) can increase the coercivity and the stability against superparamagnetic fluctuations. It has potential applications in magnetic data storage and permanent magnets. We have studied nanocomposites with FM Co or Ni NPs embedded in AF FeMn or IrMn thin films. After application of a field cooling procedure, exchange bias is observed in these nano-composites at low temperature. We observe a pronounced dependence of the exchange bias on FM volume filling factor. To determine the average size of NPs, the superparamagnetic room-temperature m-H curves of reference samples with FM NPs embedded in non-magnetic Cu films are fitted using a superposition of Langevin functions calculated for varying particle size. The fitted size distribution agrees well with the result obtained by T-SEM analysis of free standing NPs. Blocking temperatures are determined via zero field cooled (ZFC) and field cooled (FC) measurements. The switching field distributions (SFD) of NPs, which are measured by first order reversal curves (FORC), are analyzed to have a better understanding of the magnetic anisotropy. Comparison of the magnetic properties of different nano-composites reveals the influence of the exchange coupling on the magnetic energy landscape.

MA 57.19 Thu 15:00 P3

Interfacial Ferromagnetism of $LaMnO_3/SrMnO_3$ Superlattices — •Robert Gruhl and Vasily Moshnyaga — I. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

Interfaces of transition metal oxides show unique properties which cannot be observed in the constituent bulk materials. The prominent example is the formation of a 2D electron gas in $LaAlO_3/SrTiO_3$. These emergent interfacial phenomena are believed to arise due to the complex charge, spin and orbital reconstructions at the interfaces. Superlattices (SLs) of $LaMnO_3$ (LMO) and $SrMnO_3$ (SMO) were prepared on $SrTiO_3$(100) and LSAT(100) substrates using the metalorganic aerosol deposition. The growth, controlled in-situ by optical ellipsometry, results in superlattices with flat and chemically sharp interfaces as well as in an atomically smooth surface morphology.

The prepared SLs show complex magnetic behavior with high- and low-temperature ferromagnetic phases. Samples with small superlattice periods and high interface densities were prepared to investigate the interfacial magnetism. Furthermore, the substrate-induced stress effects on the magnetic properties of SLs were studied. Financial support of the Deutsche Forschungsgemeinschaft via SFB 1073 TP A02 is acknowledged.

MA 57.20 Thu 15:00 P3

Static and dynamic demagnetization of MBE grown Fe/Gd films on W(110) investigated with XMCD-R — •Dominic Lawrenz[1], Jonathan Weber[1], Wibke Bronsch[1], Tim Amrhein[1], Jan Böhnke[1], Rinat Khanbekov[1], Sarah Krüger[1], Huijuan Xiao[1], Markus Gleich[1], Kamil Bobowski[1], Xinwei Zheng[1], Niko Pontius[2], Christian Schüssler-Langeheine[2], Torsten Kachel[2], Nele Thielemann-Kühn[1], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Strasse 15, 12489 Berlin

Bilayers of ferrimagnetic Fe/Gd on W(110) were investigated at BESSY II. We examined the temperature-dependent magnetization of the bilayer element-specifically by measuring the Fe $L_{3,2}$- and the Gd $M_{5,4}$-edges using XMCD in reflection. We show that thermal magnetization-switching is dependent on the layer thickness. Further time-resolved experiments at the FEMTOSPEX facility show ultrafast demagnetization dynamics on a sub-ps timescale even for Gd, much faster than previously observed for pure Gd films. We attribute this to efficient interlayer spin currents.

MA 57.21 Thu 15:00 P3

Ferromagnetic resonance of $Mn_{1.6}PtSn$ thin films — •Peter Swekis[1,2], Anastasios Markou[1], Jörg Sichelschmidt[1], Sebastian T.B. Gönnenwein[2,3], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Center for Transport and Devices of Emergent Materials, Technische Universität Dresden, 01062 Dresden, Germany

Inverse tetragonal Mn-based Heusler-type compounds can host topological non-coplanar spin textures, such as antiskyrmions in $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$[1], that affect the electromagnetic properties in unconventional ways[2]. Investigation of the host materials and the underlying exchange mechanisms, such as the anisotropy, is therefore of utmost importance in order to control and understand the formation of those textures. The dynamic response to gigahertz frequencies becomes particularly interesting and has to be examined.

We studied $Mn_{1.6}PtSn$ thin films of various thicknesses (20-100 nm) with cavity FMR (X-Band and Q-Band) as well as broadband FMR to determine damping, g-factor, effective magnetization, anisotropy constants and temperature dependence.

[1] A.K. Nayak et. al., Nature 548, 561 (2017)
[2] P. Swekis et. al., PRM 3, 013001(R) (2019)

MA 57.22 Thu 15:00 P3

Temperature and angular dependence of the anisotropic magnetoresistance in epitaxial Mn5Ge3 film — •Yufang Xie[1,3], Ye Yuan[2], Manfred Helm[1,3], Jörg Grenzer[1], Magdalena Birowska[4], Dominik Kriegner[3,5], Shengqiang Zhou[1], and Prucnal Slawomir[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [2]Physical Science and Engineering Division, King Abdullah University of Science and Technology, 23955-6900, Thuwal, Saudi Arabia — [3]Technische Universität Dresden, 01062 Dresden, Germany — [4]Faculty of Physics, Institute of Theoretical Physics, University of Warsaw, Pasteura 5, 02093 Warsaw, Poland — [5]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany

The epitaxial ferromagnetic Mn5Ge3 films are made by ms-range diffusion of Mn into Ge (100). Temperature dependent angular magnetoresistance (AMR) measurements were performed on Mn5Ge3 films. The AMR changes strongly with temperature rising from 5K to 300K. The characteristic feature of the AMR is a twofold symmetry below 100 K and above 270K. From 100 K to 270 K, AMR shows an overall sixfold symmetry. The temperature dependent X-ray diffraction indicates there is remarkable structural deformation at 100 K, which probably results in the modification of the spin configuration from collinear to noncollinear. Considering temperature dependent magnetic properties, it is possible to conclude the transformation of spin configuration is responsible for the temperature dependent AMR.

MA 57.23 Thu 15:00 P3

Deposition and characterisation of ferromagnetic τ-MnAl thin films — •Daniel Scheffler[1], Michaela Lammel[2], Torsten Mix[2], Thomas G. Woodcock[2], Andy Thomas[2], and Sebastian T.B. Goennenwein[1] — [1]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), 01069 Dresden, Germany

τ-MnAl is a ferromagnetic phase with high uniaxial magnetocrystalline anisotropy. This makes the material attractive for permanent magnet applications, such that the magnetic properties are well studied in polycrystalline bulk samples. In contrast, the properties of single crystalline thin films, especially magnetoresistance and magnetic damping, have not been systematically investigated. We have successfully grown single crystalline τ-MnAl thin films via cosputtering. We used high resolution X-ray diffraction and SQUID magnetometry to quantify the structural and magnetic properties of our films, and find good structural quality as well as a strong perpendicular magnetic anisotropy. We also discuss the impact of the deposition parameters like substrate temperature and the post annealing temperature, which are key parameters to improve the crystalline quality and magnetic properties of τ-MnAl films.

MA 57.24 Thu 15:00 P3

Irradiation-induced magneto-structural phase transition in $Fe_{60}V_{40}$ alloy thin films — •Md. Shadab Anwar[1], Vico Liersch[1], Benedikt Eggert[3], Alexander Schmeink[1], Kay Potzger[1], Jürgen Lindner[1], Jürgen Fassbender[1], Heiko Wende[3], Olav Hellwig[1,2], and Rantej Bali[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Technical University of Chemnitz, Germany — [3]University of Duisburg-Essen, Germany

Ion beam irradiation leads to an increased saturation magnetization (M_s) in non-ferromagnetic precursors of $Fe_{60}Al_{40}$[1], $Fe_{50}Rh_{50}$[2] and $Fe_{60}V_{40}$ alloy thin films. $Fe_{60}V_{40}$ films of 40 nm thickness were prepared using magnetron sputtering onto heated SiO_2/Si substrates. The as-grown films are weakly ferromagnetic with M_s<15 kA/m for growth temperatures between 300 and 673 K. Irradiation with Ne^+ ions at 25 keV and a fluence of 1 x 10^{15} ions/cm^2 leads to an increase of M_s to 54, 549 and 246 kA/m for films grown at 300, 573 and 673 K respectively. X-ray diffraction of the as-grown films shows a broad peak at $2\theta \approx 44°$, which suggests short range ordering. Ne^+-irradiation causes the formation of the A2 structure, which is ferromagnetic. This amorphous to crystalline structural phase transition can be controlled using ion-irradiation, thus leading to a drastic increase in M_s, which can be useful in magnetic pattering applications.

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

[1] Bali, R. *et al., Nano Lett.*14, 435 (2014).
[2] Kosugi, S. *et al., Phys. Res. B* 267, 1612 (2009).

MA 57.25 Thu 15:00 P3

CPA-RPA theory for magnetic materials — •Sebastian Paischer[1], Pawel Buczek[2], and Arthur Ernst[1] — [1]Johannes Kepler Universität Linz — [2]Hochschule für Angewandte Wissenschaften Hamburg

The coherent potential approximation (CPA) is widely used for the study of electronic properties of disordered materials. In the literature several approaches to the application of the CPA to magnetic systems are present but most of them suffer from inconvenient features: They either fail to recover the Goldstone-mode or are only applicable to a rather restricted group of simple lattices and interaction types. However, recently a new promising method was published by *Buzcek et. al.* [PRB 94 054407 (2016)] which is able handle an arbitrary structure and interaction while also recovering the Goldstone-mode. We extend the method to treat finite temperature effects within the random phase approximation. In this contribution the theory of this method is shown. Our results agree with the well known spectra from the zero-temperature regime and provide insights into the temperature behavior of magnetic properties.

MA 57.26 Thu 15:00 P3

Cation order control of magnetism in double perovskite system — •Supriyo Majumder, M. Tripathi, R. J. Choudhary, and D. M. Phase — UGC-DAE CSR, University campus, Indore-452001, India

The mislocation of transition metal ions in double perovskite (DP) $A_2B^{'}B^{''}O_6$ structures from ideal alternating site occupancy, known as anti-site disordering, have a huge bearing on physical properties. With this motive, we have controlled the B-site disorders and investigated consequent signatures on magnetic ground state of R_2NiMnO_6 (R= rare earth) DP systems. Ordered RNMO is commonly believed to show two distinct magnetic phase transitions viz, PM-FM transition at T_C due to Ni^{2+}-O-Mn^{4+} super exchange interaction and at T_f due to coupling of R spins with Ni-Mn network. In addition, anomalous inverted cusp trend in M(T), two step reversibility loop behavior in M(H) and drastic reduction of M_S etc. were observed in the disordered system. Presence of intrinsic anti-site disorder results in an additional AFM coupling, mediated by Ni^{2+}-O-Ni^{2+} and Mn^{4+}-O-Mn^{4+} pairs and consequently the competition between long range FM ordering with short scale AFM interaction governs the complex magnetic behavior in RNMO. The present study provides a pathway to control magnetism by proper tunning of cation ordering in DP system.

MA 57.27 Thu 15:00 P3

Temperature- and light-induced spin-state switching at submonolayer coverage in a sublimated spin-crossover film on graphite — •Sangeeta Thakur[1], Evangelos Golias[1], Ivar Kumberg[1], Kuppusamy S. Kumar[2], Rahil Hosseinifar[1], Jorge Torres[1], Lalminthang Kipgen[1], Lucas M. Arruda[1], Chen Luo[3], Florin Radu[3], Mario Ruben[2], and Wolfgang Kuch[1] — [1]Freie Universität Berlin, Institut für Experimentalphysik, Berlin, Germany — [2]Institut de Physique et Chimie des Materiaux (IPCMS), Université de Strasbourg, France — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin Germany

Molecular self-assembly of the complex $[Fe(H_2B(pz)_2)_2$-bipy] with $COOC_{12}H_{25}$ was used to fabricate thin spin-switchable surface-bound films, with programmable intermolecular interactions [1]. Thermal- and light-induced spin-crossover behavior of 0.4 ML of $[Fe(H_2B(pz)_2)_2COOC_{12}H_{25}$-bipy] was studied on a highly oriented pyrolytic graphite (HOPG) surface by x-ray absorption spectroscopy. The highest fraction of low-spin (LS) state is found around 40 K (42 %), while at 10 K soft-x-ray-induced excited spin-state trapping decreases the fraction of LS-state molecules to 36 %. Illumination with green light at 10 K leads to a complete spin conversion to the high-spin (HS) state. Although molecules undergo a complete spin-state conversion (HS ↔ LS) both in bulk and in a thick film on SiOx [1], this effect is not observed in the submonolayer deposit on HOPG, highlighting the role of molecule–substrate interactions.

[1] K. S. Kumar et al., Adv. Mater. **30**, 1705416 (2018).

MA 57.28 Thu 15:00 P3

X-ray magnetic circular dichroism measurements on SURMOF-2 structures — •Alexei Nefedov[1], Kai Mueller[1], Lars Heinke[1], Chen Luo[2], Kai Chen[2], Florin Radu[2], Evangelos Golias[3], Wolfgang Kuch[3], and Christof Woell[1] — [1]Karlsruhe Institute of Technology, Institute of Functional Interfaces, Eggenstein-Leopoldshafen, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]Freie Universität Berlin, Institut für Experimentalphysik, Berlin, Germany

Metal-organic frameworks (MOFs) are crystalline self-assembled solids from metal compounds and organic ligands. Recently, it was found that quasi-linear metal-ion chains within a particular type of MOFs exhibit 1-D magnetic properties. Thus, Friedländer et al. reported on the ferromagnetic (FM) ordering in SURMOF-2 (Surface-mounted MOFs) [1]. Contrary to the bulk MOF-2 crystals, where Cu^{2+} ions form antiferromagnetically coupled paddlewheels, the Cu^{2+} ions in SURMOF-2 are connected via carboxylate 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 FM phase. In this study, SURMOF-2 systems (CuBDC/CuPBDC) were loaded with metalocene (manganocene and nickelocene) and their magnetic properties were investigated. The presence of the FM phase in empty SURMOF-2 systems has been confirmed with a Curie temperature of 22 K. After loading of SURMOF-2 with metalocene molecules a different behavior of magnetic properties was found. The details of these effects will be discussed. [1] Stefan Friedländer et al., Angew. Chem. Int. Ed. 2016, 55, 12683.

MA 57.29 Thu 15:00 P3

Efficient Simulation of Powder Magnetism in Single Molecule Magnets — •Hetti M. Jayawardena[1], Julius Mutschler[1], Christopher E. Anson[2], Annie K. Powell[2], and Oliver Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Institut für Anorganische Chemie, Universität Karlsruhe, KIT, Germany

The possibility for unique applications of Single-Moleculer Magnets (SMMs), e.g. in data storage devices, drives researchers to study their quantumscale behavior in greater depth. Their magnetic properties can be studied by a variety of techniques, but powder magnetization is undoubtely the most frequently employed technique. Simulating and fitting the powder magnetization curves in heterometalic 3d-4f metal clusters is challenging due to the presence of a large number of ligand field parameters, powder averaging, and relatively large Hilbert space dimensions. This leads to a massive number of diaganalization steps (ca 10^7) and expected computation times of several 100 days, even for "small" systems such as Mn_2Ln_2 SMMs. In this poster we demonstrate that exploiting sparse matrix techniques and iterative methods for simulating the experimental low temperature powder magnetization data, allows us to reduce the effort by a factor of ∼1000, making the fits practical.

MA 57.30 Thu 15:00 P3

An Efficient Magnetothermal Actuation Setup for Biomedical Applications — •Amirarsalan Asharion and Cornelia Monzel — Experimental Medical Physics, Heinrich-Heine University Düsseldorf, 40225 Düsseldorf, Germany

Magnetic hyperthermia is a promising approach for biomedical applications. Here, magnetic nanoparticles are used as heating agents to increase the temperature in the nanometer vicinity of the particle surface with minimal side-effects on the surrounding tissue. The heat dissipation arises from energy delivered to the nanoparticles in the form of an alternating magnetic field. While clinical applications are in their nascent state, live-observations of single cells could be a huge asset to improve our understanding of the heating effect on cells or on individual heat-sensitive molecules. In this work, a magnetic hyperthermia setup with a small form factor is implemented under the microscope. The setup provides an alternating magnetic field with magnetic flux densities in the range of 10-100 mT, with a frequency of 10-500 kHz, applied to a volume of 1 cm^3. We discuss the different components of this setup, the electromagnet and electric circuit, as well as essential improvements to reduce power loss.

MA 57.31 Thu 15:00 P3

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

Iron-hexadecafluorophthalocyanine ($FePcF_{16}$) is used as a oxidation catalyst. Understanding its catalysis mechanism is part of current research.

Both $FePcF_{16}$ and its mu-Oxo dimer ($[FePcF_{16}]_2O$) are already identified as steps of the oxidation cycle.

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

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

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

MA 57.32 Thu 15:00 P3

Light-, temperature-, and x-ray-induced spin-crossover tran-

sition of molecules adsorbed on a graphite surface — •Jorge Torres[1], Lalminthang Kipgen[1], Sascha Ossinger[2], Sangeeta Thakur[1], Ivar Kumberg[1], Rahil Hosseinifar[1], Lucas M. Arruda[1], Evangelos Golias[1], Chen Luo[3], Kai Chen[3], 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

The octahedral symmetry of the metal-ligand bonds of spin-crossover (SCO) molecules enables them to switch between high-spin (HS) and low-spin (LS) electronic configurations when exposed to light or temperature change. The cooperativity between SCO molecules can be studied from bottom-up growth of submonolayer coverages on well-defined substrates by X-ray absorption spectroscopy (XAS). A 0.4 monolayer coverage of $[Fe(H_2B(pypz)(pz))_2]$ was deposited on highly oriented pyrolytic graphite and measured by XAS. Analysis of the HS to LS fraction showed that light-induced excited spin-state trapping at 10 K doubles the high-spin fraction compared with the value reached by thermally induced spin-state transition at room temperature. On the other hand, due to the onset of soft-x-ray-induced excited spin-state trapping, the largest amount of LS-state molecules is reached at 60 K, while the transition temperature $T_{1/2}$ (50% HS and 50% LS) is at 300 K.

MA 57.33 Thu 15:00 P3

Atom manipulation on complex spin textures — •Andre Kubetzka, Kirsten von Bergmann, Jonas Spethmann, and Roland Wiesendanger — University of Hamburg, Germany

Atom manipulation with the tip of a scanning tunneling microscope (STM) is a widespread and straightforward technique to build complex nanostructures in an atom-by-atom fashion. Here we use atom manipulation of magnetic adatoms to investigate complex spin textures and identify the relevant (magnetic) adatom-surface interactions contributing to the manipulation process. Instead of measuring (spin-dependent) density of states a few atomic distances above the surface, as in standard (spin-polarized) STM, the manipulated adatom can be seen as an extension of the tip probing (spin-dependent) forces right at the surface [1]. This technique can be particularly useful to enhance the magnetic signal [2] or to decide whether a magnetic structure is commensurate with the atomic lattice. Examples are shown for atomic scale spin textures with different symmetries like the row-wise antiferromagnet and the 3Q state in Mn/Re(0001) and the different magnetic states found in Fe layers on Rh/Ir(111).

[1] B. Wolter, Y. Yoshida, A. Kubetzka, S.-W. Hla, K. von Bergmann, and R. Wiesendanger, Spin friction observed on the atomic scale. Phys. Rev. Lett. **109**, 116102 (2012).

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MA 57.34 Thu 15:00 P3

Optimal control assisted widefield magnetometry with nitrogen vacancy centers in diamond — •Eva Florina Grossmann[1], Gerhard Wolff[1], Philipp Jan Vetter[1], Marco Rossignolo[1,2], Thomas Reisser[3,4], Tommaso Calarco[3,4], Simone Montangero[2], and Fedor Jelezko[1] — [1]Insitut für Quantenoptik, Universität Ulm, 89073 Ulm, Germany — [2]Dipartimento di Fisica e Astronomia G. Galilei, Università degli Studi di Padova, I-35131 Padova, Italy — [3]Forschungszentrum Jülich, Institute of Quantum Control (PGI-8), 52425 Jülich, Germany — [4]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany

The nitrogen vacancy (NV) center, a point defect in the diamond lattice, offers a remarkable high magnetic sensitivity with low detection volumes. Moving from single NVs to ensemble NVs increases the magnetic sensitivity even further. Aiming at large-scale NMR with NV centers we make use of the widefield imaging technique. This technique requires homogeneous illumination as well as qubit control in form of microwave fields. Therefore, we design homogeneous magnetic AC fields by combining novel microwave structures and optimized microwave pulses, to collectively control the NVs. Apart from the significantly larger sensing area, this technique further allows a much faster acquisition time.

MA 57.35 Thu 15:00 P3

Quantitative Magnetic Force Microscopy of Magnetic Storage Media and its Avail to Probe Calibration — •Johannes Fendt[1], Jan Gurzynski[1], Siming Zou[1], Runbang Shao[2], and Berndt Koslowski[1] — [1]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Institut für Funktionelle Nanosysteme, Universität Ulm, Albert-Einstein-Allee 47, D-89081 Ulm, Germany

One-dimensional periodic magnetic structures are interesting for magnetic force microscopy (MFM) because they can be used to calibrate the probes. The simplest of such structures is the Kittel domain structure, for which the magnetisation in the sample is alternating and perpendicular to the surface. It is established that the stray field of such a structure decays exponentially with distance and the decay length is $z_0 = \frac{P}{2\pi}$ with period P. In accord with former objections, we demonstrate that the decay length shows significant deviations from the expectations. Additionally, we show how such structures can be exploited to calibrate MFM probes within the pseudo-pole model of MFM-tips.

MA 57.36 Thu 15:00 P3

Measuring Superconducting Phase Transitions with Nitrogen-Vacancy Centers in Diamond — •Domenico Paone[1,2], Dinesh Pinto[1,3], Liwen Feng[1,4], Min-Jae Kim[1,4], Gideok Kim[1], Rainer Stöhr[2], Stefan Kaiser[1,4], Bernhard Keimer[1], Jörg Wrachtrup[1,2], and Klaus Kern[1,3] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]3rd Institute of Physics and Research Center SCoPE, University Stuttgart, 70569 Stuttgart, Germany — [3]Institute de Physique, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [4]4th Institute of Physics and Research Center SCoPE, University Stuttgart, 70569 Stuttgart, Germany

The magnetism in superconductors is often accompanied by exotic electronic phases such as the vortex formation in high temperature type II superconductors. Several experimental tools have been developed to study magnetic phase transitions within these systems. However, the local sensing of dynamical mechanisms in superconductors still remains a challenge. A sensor scheme based on an atomic sized quantum sensor, the nitrogen-vacancy (NV) center in diamond, pushes the sensitivity to the local read out of weak magnetic fields. Here, we present a spatially resolved study of the Meissner effect by using the fluorescence count rate of an NV center ensemble. We are able to observe a correlation between the NV fluorescence and the Meissner state of a Lanthanum Strontium Cooper Oxide (LSCO) thin film. Implementing the NV center emission into time resolved pump probe experiments could enable the local measurement of dynamical processes.

MA 57.37 Thu 15:00 P3

The spectrum of a single molecular electron spin qubit — •Tim Dierker[1], Dinesh Pinto[2,3], and Wolfgang Harneit[1] — [1]University of Osnabrück — [2]Max Planck Institute for Solid State Research, Stuttgart — [3]Institut de Physique, École Polytechnique Fédérale de Lausanne

A single-spin electron paramagnetic resonance (EPR) measurement of $N@C_{60}$ within a C_{60} matrix using a single near surface nitrogen vacancy (NV) center was realized at low temperatures. Utilizing optically detected magnetic resonance (ODMR) a double electron-electron resonance (DEER) spectrum was obtained, showing a hyperfine structure reminiscent of $N@C_{60}$ but slightly distorted [1]. The features of the measured spectrum are compared to theoretical calculations resulting from second order perturbation theory. Here especially the possibilities for asymmetric splitting are investigated for zero-field splitting and non-isotropic hyperfine effects containing orientational dependencies.

[1] Dinesh Pinto, Domenico Paone, Bastian Kern, Tim Dierker, René Wieczorek, Durga Dasari, Amit Finkler, Wolfgang Harneit, Jörg Wrachtrup, and Klaus Kern, Readout and control of a single endofullerene electronic spin, to be published (submitted to ncomms)

MA 57.38 Thu 15:00 P3

Decoherence of a singlet-triplet superposition state under dipolar interactions of an uncorrelated environment — •Patrick Vorndamme and Jürgen Schnack — Universität Bielefeld, PF 100131, D-33501 Bielefeld

By means of an STM it was shown recently that it is experimentally possible to stimulate clock transitions between the singlet and non-magnetic triplet state of a single Heisenberg coupled spin dimer. Large decoherence times of clock like states normally refer to ensembles of spins which do not dephase. Here we are interested in decoherence of one single dimer only. For this reason we simulate how a single entity of this dimers behaves in an environment of other spins which couple to the dimer via dipolar interactions. We perform unitary time evolutions in the complete Hilbert space, including dimer and a reasonably large environment. We find that for a weak environment this approach confirms long decoherence times for the clock like state, but with stronger couplings this statement does not hold. As a reference we compare the behavior of the dimer with other, non-clock like, superposition states. Furthermore, we show that the internal dynamics of the bath plays an important role for the decoherence time of the system. In a regime where the system is weakly coupled to the bath, stronger interactions between environmental spins worsen the decoherence time up to a certain degree while if system and bath are coupled strongly, stronger interactions in the environment improve decoherence times.

MA 57.39 Thu 15:00 P3

Detecting an Electron Transfer Reaction in the Single-Molecule Regime Using a Diamond-Based Quantum Sensor — •Jan-Magnus Kurzhals, René Wieczorek, and Wolfgang Harneit — Universität Osnabrück

NV center-assisted optically detected magnetic resonance measurements are used to address the electrochemical behaviour of few neutral EPR-silent transition metal complex molecules, namely nickel bis(diphenyldithiolene), onto an oxygen-terminated diamond surface. By employing a nearby located NV center quantum sensor we gain strong evidence of a reduction process occurring on the nickel complex which we ascribe to an electron transfer from the diamond substrate. Both, Hahn echo spin locking and double electron electron resonance quantum sensing protocols, certify that our experiments probe the single-molecule regime where thermal polarization is overcome. Our insights into the nature of the electron transfer reaction are supported by quantum chemical calculations.

MA 57.40 Thu 15:00 P3

Investigation of highly ordered granular GMR structures manufactured by focused electron beam induced deposition of Co — •Björn Büker[1], Laila Bondzio[1], Daniel Kappe[1], Christian Schröder[2], Inga Ennen[1], and Andreas Hütten[1] — [1]Bielefeld University, Bielefeld, Germany — [2]FH Bielefeld University of Applied Sciences, Bielefeld, Germany

Recently focused electron beam induced deposition of metals from metal-organic precursor molecules (FEBID) has attracted a lot of attention for successfully printing 3D structures with sub-micron resolution[1]. In this work we deposited Co from the precursor $Co_2(CO)_8$ to investigate the magnetic properties of FEBID materials, which tend to be granular and embedded in a C matrix in the as deposited state. Furthermore different approaches to purification of the deposited Co structures are compared with regard to the effect on their magnetic properties. Simulations on highly ordered granular magnetic structures show a potential high giant magnetoresistance (GMR) when embedded in a weakly conducting matrix. Ultimately, we are depositing highly lattices of Co islands with FEBID in conjunction with a conducting gel matrix to verify these simulations and to assess the viability of such devices in a sensor application.

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MA 57.41 Thu 15:00 P3

Investigation of the dipole interaction in and between ordered arrangements of magnetic nanoparticles — •Nils Neugebauer, Alexander Fabian, Matthias T. Elm, Michael Czerner, Christian Heiliger, and Peter J. Klar — Institute of Experimental Physics I, Heinrich-Buff-Ring 16, 35392 Gießen, Germany

Magnetite nanoparticles (Fe_3O_4) with an average diameter of 20 nm were arranged into regular arrays of circular assemblies with well controlled dimensions by combining top-down lithographic methods with the meniscus force deposition method. Angle-dependent ferromagnetic resonance (FMR) measurements were carried out in order to characterize the specific properties of these assemblies. The measurements show that several resonances appear exhibiting a different dependence on the orientation of the external magnetic field, the degree of filling of the assemblies, and the spacings of the underlying grid. By varying the surface-to-volume ratio of the circular assemblies, we were able to manipulate the intensity and the resonance position of the resonances observed. In addition, micromagnetic simulations were performed to assign each resonance to characteristic collective oscillations within the nanoparticle assemblies.

MA 57.42 Thu 15:00 P3

3D Nano-Lithography and its Applications — •Jana Kredl[1], Christian Denker[1], Cornelius Fendler[2], Julia Bethune[4], Nina Meyer[1], Tobias Tubandt[1], Finn-Frederik Lietzow[1], Neha Jha[1], Chris Badenhorst[3], Alena Rong[5], Jakob Walowski[1], Mark Doerr[3], Raghavendra Plankar[4], Mihaela Delcea[5], Uwe T. Bornscheuer[3], Robert Blick[2], Swadhin Mandal[6], and Markus Münzenberg[1] — [1]Institute of Physics, University Greifswald, Germany — [2]Institute of Nanostructure- and Solid State Physics, University Hamburg, Germany — [3]Institute of Biochemistry, University Greifswald, Germany — [4]Institute of Immunology and Transfusion Medicine, University Medicine Greifswald, Germany — [5]Centre for Innovation Competence - Humoral Immune Reactions in Cardiovascular Diseases, University Greifswald, Germany — [6]Indian Institute of Science Education and Research Kolkata, India

3D 2-Photon-Lithography, originally developed for 3D photonic crystals, opens a wide range of new possible applications in many fields, e.g. life sciences, micro-optics and mechanics. We will present our recent applications of 3D 2-Photon-Lithography and show 3D evaporation masks for in-situ device fabrication using different deposition angles, infra-red laser light focusing lenses directly fabricated on optical fibers, tunnel structures for guiding growth of neurons [1], pillars for investigation of cell mechanics and master-mold fabrication for Polydimethylsiloxane (PDMS) micro-fluidic channels. Based on our experience we will discuss possible applications in magnetism. [1] C. Fendler et al., Adv. Biosys. 5 (2019) doi: 10.1002/adbi.201970054

MA 57.43 Thu 15:00 P3

Driving power dependency of thin-film GMI sensors with insulating layers — •Gregor Buettel, Vlad Serea, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

The dependence of the ac current on the giant magnetoimpedance (GMI) effect of Permalloy-based thin-film GMI sensors with an insulating SiO2 layer between the Cu core layer and surrounding magnetic NiFe/Ti multilayers was investigated [1]. The input power is decreased from 0 to -25 dBm without showing a decrease of the maximum GMI ratio in the skin-effect regime and decreasing the necessary ac frequency. In the ferromagnetic resonance regime a significant and unreported modification of the shape of the GMI curve shows up, especially at the Kittel mode frequency. It strongly depends on the driving power, which is contributed to microwave-assisted domain switching. In comparison with conventionally fabricated thin-film Permalloy GMI sensors [2], the control of the current path in this newly designed device geometry by insulating layers and multilevel deposition shows a strong potential to increase the GMI ratio and field sensitivity and to reduce the driving power.

[1] R. Betzholz et al., EPL 101, 17005 (2013) [2] G. Buettel et al., APL 111, 232401 (2017)

MA 57.44 Thu 15:00 P3

Fabrication and characterization of 3d-sputtered giant magnetoimpedance sensors — •Indujan Sivanesarajah, Rudolph Gerlich, Gregor Buettel, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

The influence of the variable width of a microstructured Cu spacer layer between microstructured NiFe/Ti multilayers with a fixed width on the magnetic softness, domain structure and giant magnetoimpedance (GMI) effect was investigated. The whole microstructure is fabricated by a multilevel lithography and sputtering process to accurately control alignment and width of the Cu spacer layer. Wide-field Kerr microscopy and MFM is employed to record differences of flux closure and subdomain structures at the edges of the microstructures and compared with hysteresis curves obtained by vibrating sample magnetometry of arrays of such microstructures. Additionally, SiO2 layers are deposited between the Cu and NiFe layers and their influence on the GMI studied by vector network analyser measurements. The results allow further optimization of field sensitivity and power consumption of thin-film based GMI sensors.

MA 57.45 Thu 15:00 P3

EPR on-a-Chip for Operando XES Experiments — •Ekaterina Shabratova[1], Silvio Künstner[1], Raul Garcia-Diez[2], René Grüneberger[2], Matthias Neeb[2], Katja Höflich[2], Volker Niemann[3], Rainer Pietig[3], Boris Naydenov[1], Jens Anders[4], and Klaus Lips[1] — [1]Berlin Joint EPR Laboratory, Helmholtz-Zentrum Berlin — [2]Helmholtz-Zentrum Berlin — [3]Bruker BioSpin GmbH — [4]Institute of Smart Sensors, Universität Stuttgart

Electron Paramagnetic Resonance (EPR) has proven to be an effective quantitative technique to study paramagnetic materials. Despite many advantages of this method, it still has some limitations. In particular, there are restrictions to the sample's environment due to usage of resonators, so *operando* experiments are hard to perform and the microwave frequency cannot be swept. The new EPR-on-a-Chip (EPRoC) technique allows to eliminate these limitations by using Voltage Controlled Oscillators (VCO). The sample is placed on the coil of a VCO, causing a change of its oscillation frequency that is detected as the EPR signal. EPRoC allows frequency sweeps, so a permanent magnet can be used as a source of the static magnetic field B_0. Moreover, EPRoC, being in size around 1 mm^2, can be integrated into the sample environment thus allowing *operando* investigations of different processes. Here, we will discuss the EPRoC setup and how it is planned to be implemented in the ambient pressure X-ray emission spectroscopy cell at the BESSY II synchrotron beamline. We present first steps towards this goal, and focus on the development of an electro- and permanent magnet with homogeneous magnetic field.

MA 57.46 Thu 15:00 P3

Automated evaluation of EMCD measurements — •Chris Taake, Inga Ennen, Daniela Ramermann, and Andreas Hütten — Thin Films & Physics of Nanostructures, University of Bielefeld, Bielefeld, Germany

To measure the magnetic properties of a sample at high resolution the electron magnetic circular dichroism (EMCD) has become apparent to be a good method. One big problem in evaluating EMCD measurements is, that the outcome is highly dependent on the parameters chosen for the evaluation. Combined with the limited setting options in common software this makes reproducibility almost impossible. Here we programmed a matlab based software to automate the evaluation process and make it as independent of user inputs as possible. The algorithm can operate on the basis of a spectrum image or two spectra obtained on the EMCD positions and returns the ratio between the spin and orbital magnetic moment. The calculation of the single magnetic moments is not yet provided, but can easily be added in the future by expanding the material library with the necessary values.

MA 57.47 Thu 15:00 P3

Model Based Characterization of Conductive Magnetic Bulk Materials for High Frequency Applications — •Lennart Schwan[1,2], 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, Interaktion 1, 33619 Bielefeld — [2]Thin Films & Physics of Nanostructures, Bielefeld University, Department of Physics, Universitätsstrasse 25, 33615 Bielefeld, Germany

FEM simulations are a powerful tool for the optimization of industrial high frequency applications such as induction hobs. These simulations require reliable material parameters. Magnetic bulk materials for industrial electrical applications are usually characterized with the help of ring samples, which act as magnetic core. Two coils are wound around the core to generate the magnetic field and measure the induced voltage to calculate the magnetic flux density. With increasing frequency and depending on conductivity and relative permeability the skin effect influences the measurement and makes it difficult to determine parameters characterizing the entire material. The skin effect prevents the magnetic field from completely penetrating the sample, which is normally not considered by conventional analytic approaches simply assuming a homogeneous magnetization of the magnetic core. Here, we propose an alternative model approach based on an analytical solution of Maxwell Equations representing a simplified description of the magnetic core including the skin effect in order to extract useful material parameter as input for FEM simulations.

MA 57.48 Thu 15:00 P3

Determination of the bulk spin polarization of Fe_3O_4 (111) thin films by means of spin-resolved hard X-ray time-of-flight microscopy — •Matthias Schmitt[1], Ozan Kirilmaz[1], Sergey Chernov[2], Sergey Babenkov[2], Dmitry Vasilyev[2], Katerina Medjanik[2], Olena Fedchenko[2], Yuri Matveyev[3], Andrei Gloskowski[3], Christoph Schlueter[3], Hans-Joachim Elmers[2], Gerd Schönhense[2], Michael Sing[1], and Ralph Claessen[1] — [1]Universität Würzburg, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, 97074 Würzburg, Germany — [2]Universität Mainz, Institut für Physik, 55128 Mainz, Germany — [3]DESY Photon Science, 22607 Hamburg, Germany

The electronic structure of ferrimagnetic magnetite Fe_3O_4 has previously been studied by spin-resolved soft X-ray photoemission [1,2]. However, the theoretically predicted spin polarization of -100% at the Fermi level [3] has never been experimentally shown. We have studied 30 nm thick Fe_3O_4 (111) films on ZnO(0001) using spin-resolved hard X-ray photoemission (beamline P22, PETRA III, Hamburg) with a ToF microscope [4] and a novel 3D spin detector. Benefitting from the large probing depth at photon energies of up to 5 keV surface effects like a magnetically dead layer, lowering the measured spin polarization, are negligible. We thus have been able to measure the true bulk spin polarization and discuss our findings as derived from the complex analysis of the microscopy data. [1] Phys. Rev. B **65**, 064417 (2002); [2] J. Phys.: Condens. Matter **19**, 315218 (2007); [3] J. Phys. Soc. Jpn. **68**, 1607 (1999); [4] J. Synchr. Rad. **26**, 1996 (2019)

MA 57.49 Thu 15:00 P3

Convergent electron beam diffraction: an old technique applied on new magnetic materials — •Inga Ennen, Bernhard Kaltschmidt, and Andreas Hütten — Universität Bielefeld, Dünne Schichten und Physik der Nanostrukturen, Universitätsstr. 25, 33615 Bielefeld, Germany

Convergent electron beam diffraction (CEBD) is a well-known technique for qualitative and quantitative analysis of crystal structures in a transmission electron microscope (TEM). Here, a convergent electron beam illuminates a small specimen area, typically with a diameter of 10 nm or less, resulting in a disk shaped diffraction pattern. From the intensity distribution of the diffraction pattern sample characteristics like specimen thickness, lattice parameters or features of crystal defects can be determined.

In this contribution we present CBED analysis on magnetic materials like the Co2MnSi Heusler compound as a test sample. Our focus is on the analysis of the lattice parameters and the influence of adjacent V layers on the crystal structure of the Heusler. Furthermore, the advantage of an in-column energy filter for CBED analysis will be demonstrated, which allows us to improve the signal to noise ratio of the diffraction pattern and thus to perform more precise structure analysis.

MA 57.50 Thu 15:00 P3

Investigation of nanomagnetic phenomena employing co-resonant coupled cantilever sensors — •Maneesha Sharma[1], Qifeng Pan[1,3], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden, Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany — [3]Institut für Luftfahrtantriebe, Universität Stuttgart, Stuttgart, Germany

Cantilever magnetometry is one of the most sensitive techniques used for the study of magnetic properties of small particles. [1] This approach allows to study magnetic moment, anisotropy and switching behavior of single particles and nanowires. We use the co-resonant concept for enhancing the sensitivity of dynamic mode cantilever magnetometry. The coupled modes can be easily read out at the micro-cantilever. [2]

Magnetization reversal is an important process in the study of single domain particles. Quasi periodic magnetization reversal can be induced by torsional oscillations in static magnetic fields. [3] We present a detailed numerical analysis how quasi-instantaneous events like magnetization reversal in a tiny sample attached to the nano-cantilever affect the transient oscillation of both the micro- and the nano- cantilevers of a coupled system. Furthermore, we discuss the applicability of the spring mass model for coupled cantilever systems and energy transfer mechanisms. Also, we present a novel V-shaped design of CNT based nano-cantilever.

MA 57.51 Thu 15:00 P3

Investigation of nanomagnetic phenomena employing co-resonant coupled cantilever sensors — •Maneesha Sharma[1], Qifeng Pan[1,3], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden, Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany — [3]Institut für Luftfahrtantriebe, Universität Stuttgart, Stuttgart, Germany

Cantilever magnetometry is one of the most sensitive techniques used for the study of magnetic properties of small particles. We use the co-resonant concept for enhancing the sensitivity of dynamic mode cantilever magnetometry.[1] A co-resonant coupled sensor is a combination of a standard AFM cantilever and a high aspect ratio nanowire, e.g., a carbon nanotube (CNT).

Magnetization reversal is an important process in the study of single domain particles. Quasi periodic magnetization reversal can be induced by torsional oscillations in static magnetic fields.[2] The steady state of coupled cantilever oscillations has already been investigated in detail but it*s equally important to study the transient behavior of the coupled system. We present a detailed numerical analysis how quasi-instantaneous events like magnetization reversal in a tiny sample attached to the nano-cantilever affect the transient oscillation of both the micro- and the nano- cantilevers of a coupled system. Also, we present a novel V-shaped design of the CNT based nano-cantilever.

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MA 57.52 Thu 15:00 P3

Investigation of nanomagnetic phenomena employing co-resonantly coupled cantilever sensors — •Maneesha Sharma[1], Qifeng Pan[1,3], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden, Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany — [3]Institut für Luftfahrtantriebe, Universität Stuttgart, Stuttgart, Germany

Cantilever magnetometry is one of the most sensitive techniques used for the study of magnetic properties of small particles. We use the co-resonant concept for enhancing the sensitivity of dynamic mode cantilever magnetometry. [1] A co-resonantly coupled sensor is a combination of a standard AFM cantilever and a high aspect ratio nanowire, e.g., a carbon nanotube (CNT). The coupled modes of the coupled system can easily be read at the microcantilever.

Magnetization reversal is an important process in the study of single domain particles. Quasi periodic magnetization reversal can be induced by torsional oscillations in static magnetic fields. [2] We present a detailed numerical analysis how quasi-instantaneous events like magnetization reversal in a tiny sample attached to the nanocantilever affect the transient oscillation of both the micro and the nano cantilevers of a coupled system. Also, we present a novel V-shaped design of the CNT based nanocantilever.

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MA 57.53 Thu 15:00 P3

Sensitivity improvements of EPR-on-a-Chip with rapid scan — •Silvio Künstner[1], Anh Chu[2], Boris Naydenov[1], Alexander Schnegg[3], and Klaus Lips[1] — [1]Berlin Joint EPR Lab, Helmholtz-Zentrum Berlin — [2]Institute of Smart Sensors, Universität Stuttgart — [3]EPR4Energy, Max-Planck-Institut für Chemische Energiekonversion, Mülheim a.d. Ruhr

Electron paramagnetic resonance (EPR) is the method of choice to investigate and quantify paramagnetic impurities in e.g. semiconductor devices, proteins, catalysts and molecular nanomagnets. The design of conventional EPR spectrometers, however, limits the versatility for operando measurements. Here, we present an improved design of a miniaturised EPR spectrometer, implemented on a single microchip (EPRoC). On the chip, an array of coils, each from a voltage-controlled oscillator (VCO), with a diameter of a few 100 μm is used as both, mw source and detector. Due to its compactness, EPRoC can be incorporated in growth reactors, (electro)chemical cells or in UHV environments. However, EPRoC suffers from rather poor concentration sensitivity. The usage of a VCO allows frequency sweeps with scan rates up to 2,000 THz/s rendering EPRoC perfect for rapid frequency scan EPR. Rapid scan EPR can lead to a signal-to-noise improvement especially for samples with long relaxation times, which would otherwise be saturated in continuous wave EPR. In this contribution, we demonstrate the increased sensitivity of rsEPRoC, by investigating standard EPR samples and discuss applications that will benefit from the increased sensitivity.

MA 57.54 Thu 15:00 P3

Transport of magnetic particles by custom-made magnetic pulse sequenceswith varied alteration rates — •Nikolai Weidt, Meike Reginka, and Ehresmann Arno — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

In order to design microfluidic analysis devices, a controlled and directed transport of particles is needed. The transport of superparamagnetic particles above magnetically stripe-patterned exchange bias layer systems with head-to-head and tail-to-tail orientation of the magnetization in adjacent stripe domains vertical to the long stripe axis, manufactured by ion bombardment induced magnetic patterning, is a promising approach to achieve this remote-controlled and directed transport. The superparamagnetic particles are transported by periodically transforming the magnetic field landscape above the layer system with an external magnetic field [1]. Microfluidic experiments revealed influences of the alteration rate of the applied magnetic field sequences on the particle velocities. It was observed that the particles' trajectories vary with the shape of these trapezoidal magnetic field pulses, concluding in a smoother movement of the particles for smaller alteration rates. These findings are supported by trajectories from simulations based on the consideration of the surface and magnetic forces acting on a particle. [1] D. Holzinger, I. Koch, S. Burgard, and A.Ehresmann, ACS Nano 9, 7323 (2015)

MA 57.55 Thu 15:00 P3

Study of nanoparticle dynamics in binary solutions across phase transitions — •Juri Kopp[1], Joachim Landers[1], Samira Webers[1], Soma Salamon[1], Julian Seifert[2], Karin Koch[2], Annette M. Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute for Physical Chemistry, University of Cologne

In previous magnetorheological measurements of cobalt ferrite nanoparticles in aqueous polymer solutions, Webers et al. [1] studied the thermomagnetic behavior across phase transitions showing a distinct change in magnetization. To prepare pre-aligned hybrid materials, it is important to know their stability and magnetic behavior under the influence of phase transitions such as crystallization. Here, we study the dynamics of hematite nanospindles and cobalt ferrite nanoparticles in sucrose solutions of different concentration via temperature dependent Mössbauer spectroscopy and AC-susceptometry (ACS). These methods enable us to analyze the particle mobility and particle orientation across phase transitions. ACS data obtained upon decreasing temperature reveal a supercooled state and spontaneous crystallization whereas during the heating process a mixed-fluid phase is observed, which has also been shown in the Mössbauer spectroscopy results of the sample with the smallest amount of sucrose. This work is supported by the DFG, priority programme SPP1681 (WE 2623/7-3).

[1] S. Webers et al., submitted to ACS Appl. Polym. Mat. (Jul. 2019)

MA 58: General Assembly of the Division of Magnetism

Time: Thursday 18:00–19:00 Location: POT 6

All members of the Division of Magnetism are invited to participate!

MA 59: Posters Magnetism III

Time: Friday 9:00–12:00 Location: P2/EG

MA 59.1 Fri 9:00 P2/EG

Chiral Magnetic Texture and Spin Dynamics in Magnetic Superlattices — •Luis Flacke[1,2], Valentin Ahrens[3], Simon Mendisch[3], Markus Becherer[3], Lukas Liensberger[1,2], Matthias Althammer[1,2], Hans Huebl[1,2,4], Stephan Geprägs[1], Rudolf Gross[1,2,4], and Mathias Weiler[1,2] — [1]Walther-Meißner Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physics Department, Technical University of Munich, Garching, Germany — [3]Chair of Nanoelectronics, Technical University of Munich, Munich, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Chiral magnetic textures with topological protection, so called magnetic skyrmions, are attractive for spin-based data storage and processing applications. For such applications, thin-film, all-metallic magnetic heterostructures with chiral magnetic texture stabilized by interfacial Dzyaloshinskii-Moriya interaction are ideally suited. Here, we investigate static and dynamic properties of magnetic superlattices based on the low-damping and high saturation magnetization binary alloy $Co_{25}Fe_{75}$ (CoFe). We confirm the formation of skyrmions in [Pt/CoFe/Ir] superlattices and investigate their and associated GHz-frequency resonance using magnetic force microscopy and broadband magnetic resonance spectroscopy.

We acknowledge financial support by the DFG via project WE5386/5-1.

MA 59.2 Fri 9:00 P2/EG

First-principles study of magnetic interactions in Rh/Co/Fe/Ir multilayers — •Felix Nickel, Sebastian Meyer, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel

Magnetic skyrmions are promising for the usage in data storage and logic devices. Materials, which can host small diameter skyrmions in zero magnetic field at room temperature, are suitable for such applications. Recently, it has been shown that ultrathin Rh/Co films on Ir(111) exhibit skyrmions with diameters below 10 nm at zero magnetic field [1]. On the other hand, room temperature skyrmions with diameters of 30 nm - 90 nm have been found in magnetic multilayers [2]. An antiferromagnetic coupling between magnetic layers further leads to the stabilisation and fast movement of complex spin structures [3]. Here, we study if properties, such as strong exchange frustration of ultrathin Co films as in Ref. [1] can be transferred to multilayers and how interlayer interactions can be modified. Different transition-metal multilayers consisting of Co, Fe, Ir and Rh layers have been investigated using density functional theory to examine how intra- and interlayer exchange, Dzyaloshinskii-Moriya interaction, and magnetocrystalline anisotropy can be tuned.

[1] Meyer *et al.*, Nat. Commun. **10**, 3823 (2019)
[2] Moreau-Luchaire *et al.*, Nat. Nanotechnol. **11**, 444 (2016)
[3] Parkin *et al.*, Nat. Nanotechnol. **10**, 221 (2015)

MA 59.3 Fri 9:00 P2/EG

Stability of the skyrmion lattice in Fe1-xCoxSi — •Carolina Burger[1], Andreas Bauer[1], Alfonso Chacon[1], Marco Halder[1], Jonas Kindervater[1], Sebastian Mühlbauer[2], André Heinemann[2], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, D-85748 Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, D-85748 Garching, Germany

We report on the magnetization and susceptibility of single-crystal Fe1-xCoxSi, x = 0.5, complemented by small-angle neutron scattering. In small magnetic fields, this compound hosts a hexagonal lattice of topologically non-trivial skyrmions, that may metastably persist down to lowest temperatures when field-cooled. We show that signatures characteristic of the skyrmion lattice survive field values up to the field-polarized regime as well as field inversion. This stability highlights the topological protection of skyrmions allowing to exploit their unique properties, even when being present only in metastable form.

MA 59.4 Fri 9:00 P2/EG

Atomistic spindynamic simulations on the stability of bilayer skyrmions. — •Hendrik Schrautzer[1], Stephan v. Malottki[1], Pavel F. Bessarab[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]University of Iceland, Reykjavík, Iceland — [3]ITMO University, St. Petersburg, Russia

Future room temperature skyrmionic applications require improved skyrmion stability. Recent experiments showed the possibility of stabilizing skyrmions in multilayered structures which was partly attributed to an increased amount of magnetic material [1]. Besides experimental approaches, a detail understanding of the role of interlayer exchange coupling on skyrmion stability is missing, while it is crucial for the development of skyrmion based racetracks in synthetic antiferromagnets [2]. Here we study the effect of different stackings and various coupling strengths of bilayers on the skyrmion stability using an atomistic spin model parametrized from first-principles, minimum energy path calculations and transition state theory. We investigate the multilayer system $(Rh/Pd/2Fe/2Ir)_n$ concerning skyrmion stability properties with *ab initio*-parameters [3]. For comparison we analyse exemplary stacks of the well investigated Pd/Fe/Ir system [4] for various interlayer coupling strengths and two types of stackings.

[1] Moreau-Luchaire *et al.*, Nat. Nano. **11**, 444-448 (2016)
[2] Zhang *et al.*, Phys. Rev. B **94**, 064406 (2016)
[3] Dupé *et al.*, Nat. Comm. **7**, 11779 (2016)
[4] von Malottki *et al.*, Sci. Rep. **7**, 12299 (2017)

MA 59.5 Fri 9:00 P2/EG

Lifetimes of skyrmionic states with manifold topologies in highly frustrated systems — •Moritz A. Goerzen[1], Stephan v. Malottki[1], Pavel F. Bessarab[2,3], Sebastian Meyer[1], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany — [2]University of Iceland, Reykjavík, Iceland — [3]ITMO University, St. Petersburg, Russia

A recent study [1] on a Rh/Co bilayer on Ir(111) shows an interesting energy landscape for noncollinear magnetic states due to a high degree of exchange frustration. In order to determine the suitability of the system for future spintronic technologies, we investigate the lifetimes of skyrmionic states with various topological charges. Based on an atomistic spin model parameterized from density functional theory, we perform spin dynamic simulations using the geodesic nudged elastic band method as well as transition state theory in harmonic approximation [2,3]. In determining the lifetimes of states, special care is taken for the treatment of Goldstone modes.

[1] Meyer, Perini *et al.*, Nature Comm. **10**, 3823 (2019)
[2] Bessarab *et al.*, Sci. Rep. **8**, 3433 (2018)
[3] von Malottki *et al.*, Phys. Rev. B **99**, 060409 (2019)

MA 59.6 Fri 9:00 P2/EG

Observation of compact ferrimagnetic skyrmions in $DyCo_3$ film — •Kai Chen[1], Dieter Lott[2], Andre Philippi-Kobs[3], Markus Weigand[1,4], Chen Luo[1], and Florin Radu[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Str.15, 12489 Berlin, Germany — [2]Institute for Materials Research, Helmholtz-Zentrum Geesthacht, 21502 Geesthacht, Germany — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany — [4]Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart, Germany

Owing to the experimental discovery of magnetic skyrmions stabilized by the Dzyaloshinskii-Moriya interaction in chiral magnets and/or dipolar interactions in thin films, there is a recent upsurge of interest in magnetic skyrmions with antiferromagnetic spin ordering which exhibit non-trivial topological spin configurations. Here, we report the observation of compact ferrimagnetic skyrmions in $DyCo_3$ single layer, combining x-ray magnetic scattering, scanning transmission x-ray microscopy and Hall transport techniques. These skyrmions, with an antiparallel aligned Dy and Co magnetic moments and with a characteristic lateral sizes of about ∼40 nm are formed during the nucleation and the annihilation of the magnetic maze-like domains with an obvious topological Hall effect character. Our findings provide a promising route for fundamental research in the field of antiferromagnetic spintronics towards practical applications.

MA 59.7 Fri 9:00 P2/EG

Production of Magnetic Textures in Different Dimensions — •Ross J. Knapman[1], Davi R. Rodrigues[1], Venkata Krishna

Bharadwaj[1], Jairo Sinova[1,2], and Karin Evershor-Sitte[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic

Current-induced forces can be exploited to create magnetic textures. In a 1D wire, this mechanism allows for the periodic production of domain walls [1-3] and in 2D it allows for the shedding of skyrmion-antiskyrmion pairs [4-6]. In 1D, it is possible to obtain an analytical solution to the problem which agrees well with micromagnetic simulations. In 2D there are more degrees of freedom. Within numerical simulations, we found that the degree of elasticity in the shedding process results in a change in the periodicity of the shedding, going beyond the previous results. We are constructing a model to capture this effect. Furthermore, we aim to extend our work to the investigation of the shedding of 3D magnetic textures from localised impurities. For this, we will investigate quantitative aspects such as the dependence of critical current and shedding frequency on the nature of the impurity, as well as qualitative aspects such as the nature of the objects shed.

[1] J. Shibata, et. al., PRL 94, 076601 (2005) [2] M. Sitte et. al., Phys. Rev. B 94, 064422 (2016) [3] T. P. Dao et. al., Nano Lett. 19, 5930-5937 (2019) [4] K. Everschor-Sitte, et. al., New J. Phys. 19, 092001 (2017) [5] M. Stier, et. al., PRL 118, 267203 (2017) [6] F. Büttner et. al., Nat. Nanotech. 12, 1040-1044 (2017)

MA 59.8 Fri 9:00 P2/EG

Measurement of magneto-crystalline anisotropies in MnSi by means of torque magnetometry — •Michelle Hollricher, Schorsch Sauther, Vivek Kumar, Andreas Bauer, Marc Wilde, and Christian Pfleiderer — Physik Department, Technische Universität München, D-85748 Garching, Germany

The first observation of a skyrmion lattice was reported a decade ago, in the magnet MnSi [1], stabilized by thermal fluctuations. Recently an independent second skyrmion phase was discovered in a different magnet, Cu_2OSeO_3 [2]. This second novel state can only be observed for fields applied along the <100> axes, highlighting the importance of magneto-crystalline anisotropies. So far, however, further information on the quantitative strength of magnetic anisotropies is scarce [3,4]. We report a comprehensive study of the cubic chiral magnet MnSi using torque magnetometry. We discuss our results in terms of a Ginzburg-Landau description and give an outlook on future studies on related systems.

[1] S. Mühlbauer *et al.*, Science **323**, 915-919 (2009)
[2] A. Chacon *et al.*, Nature Phys. **14**, 936-941 (2018)
[3] A. Bauer *et al.*, Phys. Rev. B **95**, 024429 (2017)
[4] T. Adams *et al.*, Phys. Rev. Lett. **121**, 187205 (2018)

MA 59.9 Fri 9:00 P2/EG

Direct Imaging of Chiral Spin Texture Distortion in Antiferromagnetic/Ferromagnetic Nanodisk structure — •Sri Sai Phani Kanth Arekapudi[1], Benny Böhm[1], Lakshmi Ramasubramanian[3], Fabian Ganss[1], Peter Heinig[1], Ciarán Fowley[3], Kilian Lenz[3], Jürgen Lindner[3], Alina M Deac[3], Manfred Albrecht[2], and Olav Hellwig[1,3] — [1]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [2]Institute of Physics, University of Augsburg, Universitätsstraße 1,86159 Augsburg, Germany — [3]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany

Chiral magnetic spin textures such as Skyrmions in Ferromagnetic (FM)/Antiferromagnetic (AFM) systems are actively explored for future data storage and signal processing devices [1]. We use an archetype NiFe disk structure which is known to stabilize a half-skyrmionic texture (magnetic vortex state). Due to the topological nature, magnetic vortex core reversal is mediated by the creation and subsequent annihilation of Bloch point singularities. Using high-resolution magnetic force microscopy, we show that the interfacial interactions between the chiral spin structure of the FM and AFM can cause significant distortion of the FM spin structure. These interfacial interactions are further harassed to stabilize phase transformations in chiral nanoscopic spin systems. Experimental observations are further supported by topological arguments and micromagnetic modeling. [1] Albisetti. et al. Commun Phys 1, 56 (2018).

MA 59.10 Fri 9:00 P2/EG

Direct Imaging of the Chiral Spin Texture Distortion in Antiferromagnetic/Ferromagnetic Nanodisk Structures — •Sri Sai Phani Kanth Arekapudi[1], Benny Böhm[1], Lakshmi Ramasubramanian[3], Fabian Ganss[1], Peter Heinig[1], Ciarán Fowley[3], Kilian Lenz[3], Jürgen Lindner[3], Alina M Deac[3], Manfred Albrecht[2], and Olav Hellwig[1,3] — [1]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [2]Institute of Physics, University of Augsburg, Universitätsstraße 1,86159 Augsburg, Germany — [3]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany

Chiral magnetic spin textures, such as skyrmions in ferromagnetic (FM)/antiferromagnetic (AFM) systems are actively explored for future data storage and signal processing devices [1]. We use an archetype NiFe disk structure which is known to stabilize a half-skyrmionic texture (magnetic vortex state). Due to the topological nature, the reversal of the magnetic vortex core is mediated by the creation and subsequent annihilation of Bloch point singularities. Using high-resolution magnetic force microscopy, we show that the interfacial interactions between the chiral spin structure of the FM and AFM can cause significant distortion of the magnetic vortex structure. These interfacial interactions are further used to stabilize phase transformations in chiral nanoscopic spin systems. Experimental observations are further supported by topological arguments and micromagnetic modeling. [1] Albisetti. et al. Commun Phys 1, 56 (2018).

MA 59.11 Fri 9:00 P2/EG

Symmetry of skyrmion and antiskyrmion dynamics with spin transfer and spin orbital torques — •Mariia Potkina[1,2], Igor Lobanov[1,2], and Valery Uzdin[1,2] — [1]ITMO University, Saint Petersburg, Russia — [2]Saint Petersburg State University, Russia

Lattice models of skyrmions and antiskyrmions in ferromagnetic and antiferromagnetic materials are considered taking into account the Heisenberg exchange, magnetic anisotropy, Dzyaloshinskii-Moriya interaction and interaction with external magnetic field. The skyrmionic and antiskyrmionic states are shown to be in one to one correspondence under certain transformation of spin configurations and vector parameters in the Hamiltonian. Without long range magnetic dipole interaction this transformation conserves the energy of the system and the shape of the energy surface. Therefore activation energies for annihilation of both states and the prefactors in Arrhenius law for lifetime are exactly the same for correspondent structures.

For the current driven dynamics, both spin-transfer and spin-orbit torques are considered and it is demonstrated how the current has to be transformed in both cases to match the dynamics of skyrmions and antiskyrmions. This makes it possible to determine the dynamics of an antiskyrmion if the dynamics of the corresponding skyrmion is known and to predict for which orientation the antiskyrmion moves in the direction of the applied spin polarized current.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138).

MA 59.12 Fri 9:00 P2/EG

Anisotropic Skyrmion Diffusion — •Klaus Raab[1], Nico Kerber[1,2], Markus Weissenhofer[3], Kai Litzius[1,2], Jakub Zázvorka[1], Ulrich Nowak[3], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, DE-55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Fachbereich Physik, Universität Konstanz, Universitätsstraße 10, DE-78457 Konstanz, Germany

Thermally activated processes are intrinsic effects in every physical system and their understanding key to the underlaying dynamics of such systems. Using skyrmions, magnetic, topologically stabilized spin structures, we investigate the thermal diffusion dynamics in specifically tailored metal-multilayer. We find that for low pinning materials stacks, the thermal diffusion dominates the dynamics and allows for stable skyrmions at room temperature that move by thermal activation [1-3].

These stable Skyrmions allow for a wide range of possible applications in logic, data storage or Brownian token computing devices. In Brownian circuits the control of the skyrmion diffusion and the implementation of certain control is necessary. We show that by applying an in-plane field the skyrmion diffusion becomes anisotropic and controllable, while the absolute values of the diffusion coefficients are also drastically affected. We can analytically and numerically explain the anisotropic diffusion due to an elliptical deformation of the skyrmions by the application of the in-plane field, which leads to a preferential diffusion axis.

MA 59.13 Fri 9:00 P2/EG

Topological Magnetic Textures in Antiskyrmion Hosting Heusler Compounds Mn_xYZ — •Jacob Gayles, Yan Sun, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden

Recently, the Heusler compounds $Mn_{1.4}PtSn$ and $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ were shown to stabilize an antiskyrmion lattice above room temperature and without an external magnetic field. These Heusler compound forms in a superstructure with the D_{2d} symmetry, which allows for an anisotropic Dzyaloshinskii-Moriya interaction (DMI) perpendicular to the tetragonal axis. Furthermore, many of these compounds show a spin reorientation transition where the topological Hall effect is much larger below the transition than above in the known antiskyrmion regime. We perform density functional theory calculations of Mn_xYZ compounds to extract the relevant exchange interactions that determine the rich phase diagrams in these materials. The exchange interactions are between the large moments on the Mn atoms $\sim 4\mu_B$, which show magnetic states that are non-collinear ferrimagnetic up to the spin reorientation. The major role of the spin-orbit driven DMI is due to the Z ion, either In, Ga, Sn or Sb where the Y ion (Ru, Rh, Pd, Ir, or Pt) d-states lowered in energy due to the Jahn-Teller distortion. The content of Mn also plays a large role in the stabilization of the magnetic textures. The electron occupation can be tuned by the Y ion, either In, Sn or Sb. We last calculate the anomalous Hall effect and topological Hall effects in these regimes, to capture the influence of the electronic structure on the Berry curvature.

MA 59.14 Fri 9:00 P2/EG

Topological Defects in Helimagnetic Spin Textures — •Erik Lysne[1,2], Mariia Stepanova[1,2], Peggy Schoenherr[3], Jan Masell[4], Laura Köhler[2,5], Achim Rosch[6], Naoya Kanazawa[7], Yoshinori Tokura[4,7], Markus Garst[8], and Dennis Meier[1,2] — [1]NTNU, Trondheim, Norway — [2]QuSpin NTNU, Trondheim, Norway — [3]ETH Zurich, Zürich, Switzerland — [4]RIKEN , Wako, Japan — [5]Technische Universität Dresden, Dresden, Germany — [6]Universität zu Köln, Köln, Germany — [7]University of Tokyo, Tokyo, Japan — [8]Karlsruhe Institute of Technology, Karlsruhe, Germany

In non-centrosymmetric ferromagnets, the Dzyaloshinskii-Moriya interaction is symmetry-allowed and the magnetic energy can be reduced by canting the spins, resulting in complex spin spiral structures. Examples include transition-metal silicides and germanides, which crystallize in the B20 structure. Among the B20 magnets, the highest known transition temperature is found in FeGe, which also has a remarkably low magnetic anisotropy. Because of this low anisotropy, the orientation of the helix can assume any direction in the surface plane. Most interestingly, completely new types of domain walls emerge between regions with different orientation of the helical structure in the ground state. These novel helimagnetic domain walls have interesting and unusual physical properties, such as non-trivial topology. Furthermore, they bear a striking resemblance to cholesteric liquid crystals, but on a very different length scale. We use magnetic force microscopy to investigate these domain walls and associated defects, with the goal of demonstrating new opportunities for future spintronic applications.

MA 59.15 Fri 9:00 P2/EG

μSR 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 (μSR) experiments on oriented single crystals. In zero magnetic field, the spontaneous rotation signals allow 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, what is interpreted with a spin-reorientation. The observed changes at low temperature and in the applied field indicate that this phase has not 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 59.16 Fri 9:00 P2/EG

Dynamics of non-trivial topological states without the need for Dzyaloshinskii-Moriya interaction — •David Eilmsteiner[1], Levan Chotorlishvili[2], Xi-guang Wang[3], Martin Hoffmann[1], and Arthur Ernst[1,4] — [1]Institute for Theoretical Physics, Johannes Kepler University Linz, 4040 Linz, Austria — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany — [3]School of Physics and Electronics, Central South University, Changsha 410083, China — [4]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany

The current 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 technological applicability is the limited range of materials in which skyrmions intrinsically occur – for instance the Dzyaloshinskii-Moriya interaction is usually required. Nevertheless, making use of special material combinations, it is possible to induce skyrmions in a much wider range of materials. The aim of our research is to study the dynamics of various non-trivial topological configurations in such systems (e.g. bi-skyrmions in a $La_{0.7}Sr_{0.3}MnO_3$-$SrRuO_3$ bilayer with Co disks on top). Therefore, we use the toolkit of micro-magnetism equipped with parameters such as the exchange stiffness or the magneto-crystalline anisotropy gained from first-principles calculations.

MA 59.17 Fri 9:00 P2/EG

Current-induced instabilities of magnetic skyrmions due to spin-transfer torques; speed limits for skyrmions — Jan Masell[1,2], •Benjamin F. McKeever[3], Davi R. Rodrigues[3], and Karin Everschor-Sitte[3] — [1]Institute for Theoretical Physics, University of Cologne, 50937 Cologne, Germany — [2]RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan — [3]Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany

Magnetic skyrmions in chiral ferromagnets can be efficiently moved by spin-polarized electric currents, and controllable motion at high speeds is particularly desirable for spintronics applications. Upon increasing the current strength, however, skyrmions deform from their trademark circular shape, which limits their utility. We analyze single skyrmions in motion for different micromagnetic parameters and driving currents, due to spin-transfer torques for smooth magnetic textures, and systematically map out how the skyrmion shape distorts. For compact skyrmions at uniaxial anisotropies far above the critical anisotropy for a uniform ground state, we find that at large current densities the skyrmion assumes a non-circular shape with a tail, reminiscent of a shooting star. For larger, softer, skyrmions closer to the critical anisotropy, we observe a critical current density above which skyrmions become unstable and elongate to an arbitrary extent; however, above a second critical current density the shooting star solution can also be recovered for these skyrmions.

[1] J. Masell, B.F. McKeever et al. (in preparation), (2020)

MA 59.18 Fri 9:00 P2/EG

Double Topological Hall Effect as a signature for Skyrmions and Antiskyrmions — •Pranava Keerthi Sivakumar[1], Börge Göbel[1], Edouard Lesne[1], Anastasios Markou[2], Jyotsna Gidugu[1], James Taylor[1], Hakan Deniz[1], Jagannath Jena[1], Claudia Felser[2], Ingrid Mertig[1,3], and Stuart.S.P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany. — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Strasse 40, 01187 Dresden, Germany. — [3]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany.

Topological magnetic textures such as skyrmions and antiskyrmions are typically observed in materials belonging to different symmetry groups where the bulk Dzyaloshinskii-Moriya interaction (DMI) is either isotropic or anisotropic and leads to the stabilization of either skyrmions or antiskyrmions respectively. Recently, both these topological objects were found in the same inverse Heusler crystal, whose D2d symmetry is expected to stabilize only antiskyrmions. In this poster, we report on the observation of two distinct peaks in the topological Hall effect (THE) exhibited by thin films of Mn2RhSn. These features are later shown, phenomenologically and through transport simulations, to be direct signatures of two topologically distinct chiral spin textures, namely skyrmions and antiskyrmions. Utilizing THE studies, we infer that skyrmions are predominantly stabilized at lower temperatures where dipolar interactions dominate, while antiskyrmions are present at higher temperatures over a wide range of magnetic fields.

MA 59.19 Fri 9:00 P2/EG

Edges modes in FM-SC hybrid structures — •Jasmin Bedow[1,2], Eric Mascot[2], Stephan Rachel[3], Dirk Morr[2], and Götz Uhrig[1] — [1]TU Dortmund — [2]University of Illinois at Chicago, Chicago, USA — [3]University of Melbourne

We investigated edge modes in two-dimensional FM-SC hybrid structures, composed of an s-wave superconductor and magnetically ordered adatoms placed on top of the superconducting substrate.

Our results show topological properties for a 3Q-ordered structure of the adatoms' spins. For this ordering, we computed the topological phase diagram and the zero-energy local density of states for islands and ribbons of adatoms. For these, Majorana modes emerge depending on the chosen parameter set and a supercurrent is found along the edge of the magnetic structure.

Furthermore, we investigated different types of magnetic domains, including domains created by shifts in the unit cell, a reversal of the spins' orientation and a reversal of the superconducting order parameter. The emerging edge modes show interesting dispersions and we determined whether they are Majorana modes.

MA 59.20 Fri 9:00 P2/EG

Fast Mapping of Magnetic States in Perpendicular Magnetic Anisotropy Systems — •Ruslan Salikhov[1], Fabian Samad[1], Leopold Koch[2], Benny Böhm[2], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Chemnitz University of Technology, Chemnitz, Germany

Synthetic antiferromagnets (SAF) with perpendicular magnetic anisotropy (PMA) are hosting a large variety of magnetic states ranging from AF coupled states to ferromagnetic (FM) stripe domain configurations and their mixtures [1]. Magnetic states in SAFs can be conveniently adjusted using the design parameters of the magnetic multilayers (ML), e.g. their individual layer thicknesses and their number of repetitions [1]. The remanent domain state mostly depends on the specific demagnetization routine via an external magnetic field [1-3]. Here we present the fast mapping of magnetic states in SAFs for different demagnetization protocols and ML parameters by means of monitoring the remanent magnetization (RM) during the AC or DC demagnetization process itself and performing magnetic force microscopy (MFM) imaging at intermediate specific states of interest. The aligned stripe domain state is characterized by almost zero RM, whereas bubble domains manifest themselves by an enhanced RM. Our screening protocol allows the fast and convenient detection of magnetic bubble states in all type of PMA systems including SAFs. [1] O. Hellwig, et al., JMMM 319, 13-55 (2007). [2] K. Chesnel, et al., Phys. Rev. B 98, 224404 (2018). [3] L. Fallarino, et al., Phys. Rev. B 99, 024431 (2019).

MA 59.21 Fri 9:00 P2/EG

Interlayer Dzyaloshinskii-Moriya interaction in low-dimensional magnetic structures — •Maria E. Konstantinova, Levente Rózsa, Elena Y. Vedmedenko, and Roland Wiesendanger — Department of Physics, University of Hamburg, Hamburg, Germany

Interfacial Dzyaloshinskii-Moriya interaction (DMI) is responsible for many interesting chiral phenomena in interfacial magnetic multilayer systems. Particularly, it causes a formation of spin spirals within an interfacial plane. Recent theoretical and experimental studies highlighted the role of the interlayer DMI, in addition to the intralayer DMI, in interfacial systems [1-3]. However, it is still not known how the interlayer DMI influences the magnetic texture appearing due to the intralayer DMI. Here, we study analytically and with Monte Carlo simulations the magnetic structure in multilayers with competing interlayer and intralayer DMI. We find that the interlayer coupling changes the relative phase of rotation of the intralayer spin spirals. If the interfacial DM vector in two subsequent layers is opposite, then the spirals become anharmonic due to the intralayer DMI. Additionally, a chiral rotation across the layers appears. The ground states for different ratios of the interlayer and the intralayer DMI will be discussed.

[1] E. Y. Vedmedenko et al., Phys. Rev. Lett. 122, 257202 (2019).
[2] A. Fernández-Pacheco et al., Nat. Mater. 18, 679 (2019).
[3] D. S. Han et al., Nat. Mater. 18, 703 (2019).

MA 59.22 Fri 9:00 P2/EG

Lifetimes of large magnetic structures — •Moritz Sallermann[1,2], Stefan Blügel[1], and Hannes Jónsson[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Science Institute and Faculty of Physical Sciences, University of Iceland, VR-III, 107 Reykjavík, Iceland

The thermal stability of certain spin configurations is of tremendous importance in the design of experimental setups and spintronics devices. In the framework of harmonic transition state theory, this critical property can be estimated. Such a calculation produces the rate of a specific reaction, following a known transition path from the initial configuration to a final state. The reaction rate is determined from local properties of the energy landscape around two designated points along the transition path - the initial state and the saddle point.

Specifically it is required to know the ratio between the determinant of the Hessian matrix at the initial and at the saddle point configuration, which is linked to the entropic bottleneck of the reaction.

As one considers large systems, however, the straightforward approach of computing all eigenvalues of the Hessian, turns out to be much too computationally expensive and therefore not feasible. We explore an alternative avenue of obtaining the transition rate via statistically estimating the entropic contribution, thus avoiding the expensive eigenvalue decompositions. We apply this approach to lifetime estimations for large magnetic structures, modelled as classical atomistic spins with an extended Heisenberg Hamiltonian.

MA 59.23 Fri 9:00 P2/EG

Magnetic structure of Pd/Fe/Ir(111) islands confined by a ferromagnet — •Kathrin Raeker, Jonas Spethmann, Elena Y. Vedmedenko, and Roland Wiesendanger — Depertement of Physics, University of Hamburg, Hamburg, Germany

We have employed stochastic Landau-Lifshitz-Gilbert spin dynamics calculations as well as Monte Carlo simulations to study the magnetic structure in laterally confined Pd/Fe/Ir(111) islands interfacing to Co/Fe/Ir(111). Monolayers of Co on Fe/Ir(111) show a strong ferromagnetic signature, whereas ultrathin films of Pd/Fe/Ir(111) form spin spirals at zero magnetic field and skyrmions at finite perpendicular fields [1]. While free-standing Fe/Ir(111) islands have been explored theoretically and experimentally [2], the influence of the interfacing of Co on the magnetic structure of spin spirals in Pd/Fe/Ir(111) is not known yet.

In the field-free regime, we find a strong coupling of the wave vector of the magnetic spiral with the close-packed edges of Fe nanostructures with the spin spiral running perpendicular to the closed-packed edge. If the island is interfaced by Co, the spin spiral is oriented along the island's rim. These numerical findings can be explained by analytical considerations of the spatially dependent energy of the spin texture, and opens new possibilities in the engineering of magnetization states in laterally confined nanostructures.

[1] N. Romming et al., Science 341, 636 (2013).
[2] J. Hagemeister et al., Phys. Rev. Lett. 117, 207202 (2016).

MA 59.24 Fri 9:00 P2/EG

Floquet Time Crystal in a Chiral Magnet — •Nina del Ser, Lukas Heinen, and Achim Rosch — Insitut für theoretische Physik, Universität zu Köln

We investigate how driving the conical phase of a chiral magnet with a time-periodic magnetic field can lead to the formation of Floquet time crystals: periodic perturbations of the steady-state magnetization in time as well as space. Our model is a 3D cubic spin lattice with Heisenberg and Dzyaloshinskii-Moriya interactions. We first obtain analytical expressions for the time-dependent magnetization of the steady state. We then expand around this time-dependent steady state using the Holstein-Primakoff formalism for bosonic excitations. Calculating the band spectrum requires the use of Floquet theory as it is a time-periodic problem. The Floquet band spectrum suggests the existence of unstable modes at certain resonant frequencies leading to the formations of new Floquet time crystal states, also observed in numerical experiments.

MA 59.25 Fri 9:00 P2/EG

Controlled creation of magnetic stray field landscapes in synthetic antiferromagnets with perpendicular anisotropy by means of focused ion beam irradiation — •Fabian Samad[1,2], Leopold Koch[2], Gregor Hlawacek[1], Sri Sai Phani Kanth Arekapudi[2], Miriam Lenz[1], and Olav Hellwig[1,2] — [1]Helmholtz-

Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Chemnitz University of Technology, Chemnitz, Germany

Recently it was shown that a combination of magnetic field application and focused ion beam irradiation can be employed to create different magnetic stray field landscapes above the surface of exchange bias systems [1]. In our work, instead, we use layered synthetic antiferromagnets with perpendicular anisotropy as a starting state, which exhibits a great variety of magnetic states depending on the specific magnetic energy balance within the system [2]. We are able to stabilize different magnetic states locally and controllably, giving rise to a well-defined stray field landscape. Additionally, we show that the magnetic textures can be modified by an external magnetic field in a controlled way, enabling the post-irradiation modification of the stray field landscapes. These stray fields might be used to stabilize certain magnetic domain formations in a soft-magnetic overlayer deposited on top of the synthetic antiferromagnet, which could be utilized as a spin wave guiding infrastructure. [1] Mitin et al., Nanotechnology 29, 355708 (2018). [2] Hellwig et al., J. Magn. Magn. Mater. 319, 13-55 (2007).

MA 59.26 Fri 9:00 P2/EG

Time-resolved imaging of vortex domain wall motion and chirality rectification in curved nanowires — •Daniel Schönke[1], Robert M. Reeve[1], Hermann Stoll[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart, Germany

Controlling the vortex domain wall (DW) chirality is important for chirality-encoded DW logic and for other devices based on propagating DWs due to chirality-dependent motion behaviour. Among several ideas to control the chirality, spin rectifying corners and end domains have been proposed [1,2]. We investigated domain-wall motion and chirality control in asymmetric $Ni_{80}Fe_{20}$ halfring pairs by time-resolved imaging using a scanning electron microscope with polarization analysis [3]. This method allows us not only to directly observe the dynamics with nanosecond resolution, but also to determine the probabilities of different switching pathways and the associated chirality protection. The experiments were complemented by micromagnetic simulations. The results reveal that the control of chirality by curvature works with very high reliability, whereas the chirality at the wire ends is less reproducible. Furthermore the attractive interaction of vortex DWs in adjacent wires plays a key role in the dynamics with the interaction being stronger for DWs with the same chirality. [1] Omari et al., *Appl. Phys. Lett.* **107**, 222403 (2015) [2] Wilhelm et al., *Appl. Phys. Lett.* **95**, 252501 (2009) [3] Schönke et al., *Rev. Sci. Instrum.* **89**, 083703 (2018)

MA 59.27 Fri 9:00 P2/EG

Magnetic domain wall propagation in periodically modulated wires — •Olga Lozhkina, Robert Reeve, Gerhard Jakob, and Mathias Kläui — Institut für Physik, Johannes Gutenberg- Universität Mainz, 55099 Mainz, Germany

In thin confined wires where the domain structure is governed by the shape anisotropy, for soft magnetic wires domain walls (DWs) can be described as quasiparticles moving under external field so they can be implemented for magnetic field sensing [1-2]. However, DW propagation mechanism has a complex dependence on field and a high stochasticity of pinning depending on the DW spin structure. The periodic modulation of the magnetic wire width was predicted to suppress the Walker breakdown, thus conserving the DW spin structure. A thorough control of the domain wall spin structure can make the propagation reproducible and evades the sensor failure. Our simulations show that wire width modulation with an appropriate amplitude and period fully suppresses the WB. It was also shown that the wire width modulation decouples brunches at the intersection region of the sensor making the DW propagation reproducible [2]. Experiments utilizing short current pulses producing an Oersted field which displaces the DWs in the magnetic wires and Magneto-Optical Kerr Effect for optical detection of the DWs positions were performed to study the influence of the periodic modulation on the DW propagation in soft magnetic wires. [1] M. Diegel et al., IEEE Trans. Magn. 40, 2655 (2004) [2] B. Borie et al., Phys. Rev. Appl. 8, 024017 (2017) [3] E. Semenova et al., J. Appl. Phys. 124, 153901 (2018)

MA 59.28 Fri 9:00 P2/EG

Manipulation of laterally homogeneous vertical AF domain walls in Synthetic Antiferromagnets with Perpendicular Magnetic Anisotropy — •Benny Böhm[1], Lorenzo Fallarino[2] und Olav Hellwig[1,2] — [1]Institute of Physics and MAIN, Chemnitz University of Technology, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany

Antiferromagnets (AFs) are of emerging interest due to their wide variety of useful properties at the micro and nanoscale. Despite the macroscopically vanishing magnetic remanent moment and therefore high stability with respect to external magnetic field, AFs may provide other unique magnetic static states as well as promising characteristics for dynamic applications like high domain wall velocities and excitation frequencies into the THz regime.

Synthetic antiferromagnets (SAFs), consisting of AF-coupled ferromagnetic layers via thin non-magnetic spacer layers, maintain the main characteristics of intrinsic AFs. Additionally, SAFs offer a high degree of tunability and easy integration, thus making them interesting for a wide range of applications.

One unique AF phenomenon, which can be efficiently observed in SAFs, is the Surface Spin Flop (SSF). During the SSF-reversal, a laterally homogeneous vertical AF domain is nucleated. Combining the SAF with perpendicular magnetic anisotropy allows to easily manipulate even locally the films magnetic properties. Thereby, the vertical AF domain wall can be stabilized even at remanence, allowing to choose between multiple coexisting remanent states.

MA 59.29 Fri 9:00 P2/EG

Real-time dynamics of classical spins coupled to the boundary of a Kane-Mele model — •Robin Quade and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

The real-time dynamics of the two-dimensional Kane-Mele model with a single or several classical impurity spins coupled to the boundary of the electronic system is investigated numerically. To this end, we employ a high-order Runge-Kutta technique to solve the coupled system of equations of motion, i.e., the canonical equations of motion for the classical spin dynamics and the Liouville-type equation for the one-particle reduced density matrix of the electronic system.

At each instant of time, the classical impurity spins act as local magnetic fields and thus, via the Kondo-like exchange coupling, locally break time-reversal symmetry (TRS). We consider the topologically nontrivial phase of the Kane-Mele model and study the impact of the bulk-boundary correspondence and the spin-momentum locking of the TRS-protected surface states on the real-time dynamics of the impurity spins.

MA 59.30 Fri 9:00 P2/EG

Photocurrents in 3D Topological insulators Hall bar and nanowire devices — •Nina Meyer[1], Thomas Schumann[1], Eva Schmoranzerová[2], Kevin Geishendorf[3], Gregor Mussler[4], Jakob Walowski[1], Petr Nemec[2], Andy Thomas[3], Kornelius Nielsch[3], Detlev Grützmacher[4], and Markus Münzenberg[1] — [1]Institute of Physics, University of Greifswald, Greifswald, Germany — [2]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic — [3]IFW Dresden, Institute for Metallic Materials, Dresden, Germany — [4]Inst. for Semiconductor Nanoelectronics, PGI-9, Forschungszentrum Jülich, Germany

It has been demonstrated experimentally that illuminating a topological insulator (TI) with circular polarized light generates spin-polarized surface currents, since spin-momentum locking is present [1]. In this poster, we will sum up our results on photocurrent measurements on $(Bi, Sb)_2Te_3$ thin film Hall bar structures and Bi_2Se_3 core-shell nanowires. The laser light is moved in a 2D pattern across the sample surface and the photocurrent is measured as a function of the polarisation at every laser position. Therefore, the different contribution to the photocurrent can be displayed as spatially resolved 2D maps. For the Hall bar structure, a lateral accumulation of spin polarization at the TIs edges due to the spin Nernst effect is found [2]. For the nanowires, a constant spin polarized current far off the contacts is found and the edge effects of the Au/TI layer stack are investigated.

[1] J.W. McIver et al., Nature Nanotechnology 7, 96-100 (2012)

[2] T. Schumann et al., arXiv:1810.12799 (submitted)

MA 59.31 Fri 9:00 P2/EG

Interplay of chemical disorder and layer native defects within topological insulators — •Jakub Šebesta and Karel Carva — Charles University, Faculty of Mathematics and Physics, Department of Condensed Matter Physics, Ke Karlovu 5 121 16 Praha 2, The Czech Republic

Material can host several kinds of native defects, which includes chemical defects as well as structural defects. In general, it leads to the modification of their physical properties including magnetic and transport ones. Therefore, in the present work based on ab-initio calculations we focus on the influence of the layer defects, namely the experimentally evidenced twinning planes, on the properties of the well known bismuth chalcogenide topological insulators Bi_2Se_3 and on their interplay with point defects concerning not only the native ones but also magnetic doping. We employ the TB-LMTO-ASA method based on the layered Green's functions, which allows us to treat the chemical disorder efficiently in the framework of the CPA. The distribution of the twinning planes within multilayer sample is discussed together with the dependence of their formation energy in relation to the type of the point defects and their concentration. Furthermore, the interplay between layer defects and magnetic dopants and their magnetism is emphasized. Finally, the impact of the presence of the structure defects on the electron structure, particularly on the surface states and on the surface gap, is estimated.

MA 59.32 Fri 9:00 P2/EG

Static and dynamic magnetic properties of $(MnBi_2Te_4)(Bi_2Te_3)_n$ probed using electron spin resonance technique. — •Alexey Alfonsov[1], Kavita Mehlawat[1], Anna Isaeva[1,2], Alexander Zeugner[3], Anja U. B. Wolter[1], Vladislav Kataev[1], and Bernd Büchner[1,2] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany — [2]Faculty of Physics, TU Dresden, 01062 Dresden, Germany — [3]Faculty of Chemistry and Food Chemistry, TU Dresden, 01062 Dresden, Germany

$(MnBi_2Te_4)(Bi_2Te_3)_n$ represents a family of van der Waals materials which exhibit a coexistence of topologically nontrivial surface states with intrinsic magnetism. Such unusual combination of properties renders this natural heterostructures very attractive for investigations since it enables a number of exotic phenomena, which in turn might find potential applications in spintronics. In this work we address static and dynamic magnetic properties of the title material in ordered and disordered states using multifrequency and high field electron spin resonance technique. One example of our finding is the observation in $MnBi_2Te_4$ of surprisingly anisotropic spin dynamics of bulk conduction electrons and Mn localized states which, as we argue, could be responsible for the persistence of the band gap in the topological surface state even above the magnetic ordering temperature.

MA 59.33 Fri 9:00 P2/EG

Magnetic and Anomalous Transport Properties of Hexagonal -$Mn_{3+\delta}Ge$ — •Venus Rai, Shibabrata Nandi, Subhadip Jana, Jörg Persson, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute PGI, JARA-FIT, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

Topological quantum materials have attracted enormous attention since their discovery due to the observed anomalous transport properties, which originate from the non-zero Berry curvature. $Mn_{3+\delta}Ge$ has gained special attention because of its large anomalous transport effects that persist starting from Néel temperature (365 K) down to 2 K. Hexagonal - $Mn_{3+\delta}Ge$ stabilizes in the range of $\delta = 0.25$ to 0.55. We have observed larger anomalous Hall effect with very small hysteresis (<200 Oe) for high Mn concentration in $Mn_{3+\delta}Ge$. To establish the claim for the existence of Weyl points in $Mn_{3+\delta}Ge$, transverse and longitudinal magneto-resistance (MR) was also performed with field and current applied along several combinations of x, y, z crystallographic axes. Negative MR is observed in some cases even when magnetic field (B) is perpendicular to the current (I) direction. However, in case of $I\|B\|x$, negative MR is observed with different slopes below and above 2 T. Angle dependent measurement (between I and B) shows that the negative MR with higher slope (observed below 2 T) is possibly originating due to the chiral anomaly.

MA 59.34 Fri 9:00 P2/EG

GdBiTe: A candidate magnetic topological semimetal — •Paul Gebauer[1], Laura T. Corredor Bohorquez[2], Anja U. B. Wolter[2], Bernd Büchner[2,3], Thomas Doert[1], and Anna Isaeva[2,3] — [1]Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Dresden, Germany — [2]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — [3]Faculty of Physics, Technische Universität Dresden, Dresden, Germany

Interacting topological materieals with a non-trivial topology of the electronic band structure and intrinsic magnetic ordering hold promises for spintronic applications. GdSbTe was reported as an antiferromagnetic nodal-line semimetal [1]. We discover GdBiTe with even stronger spin-orbit coupling. The powder is synthesized by a solid-state reaction of the elements. The crystal structure (space group $P4/nmm$; $a = 436.9(1)$ pm, $b = 924.3(1)$ pm) is determined by single-crystal X-Ray diffraction. The ground state from the first principles calculations is antiferromagnetic with a calculated magnetic moment $7.32\mu_B$ (expected $7.94\mu_B$ for Gd(III), $J = \frac{7}{2}$). Field- and temperature-dependent magnetization and specific heat measurements on polycrystalline samples show an antiferromagnetic state and a metamagnetic transition at 15 K, which nature remains to be eludicated. [1] M. M. Hosen, et al., Sci. Rep. 8, 13283 (2018).

MA 59.35 Fri 9:00 P2/EG

Lattice instability of the novel multiferroic $Cu_9O_2(SeO_3)_4Cl_6$ — •Ksenia Denisova[1,2], Dirk Wulferding[1], Dirk Menzel[1], Olga Maximova[2], Helmuth Berger[3], Jiunn-Yuan Lin[4], Alexander Vasiliev[2], and Peter Lemmens[1] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]Faculty of Physics, MSU, Moscow, Russia — [3]EPFL, Lausanne, Switzerland — [4]NCTU, Hsinchu, Taiwan

Due to the combination of lone-pair ferroelectricity and d-electron magnetism high T_c multiferroicity is observed in many transition metal oxohalides [1,2]. The new type-I multiferroic $Cu_9O_2(SeO_3)_4Cl_6$ exhibits long range magnetic ordering at $T_N = 37$ K and a polar ordering at $T_E = 270$ K [3]. Our Raman study reveals signs of both magnetic and electric phase transitions: spin-phonon coupling below T_N, appearance of new lines of magnetic origin for $T<T^* = 16$ K, and a symmetry lowering for $T<T_E$. Evidence for an additional lattice instability at 100 K is reported. Work supported by NUST "MISiS" Grant No. K2-2017-084. [1] L. Zhao, et al., Sci. Adv. 2, e1600353 (2016). [2] H. C. Wu, et al., PRB 95 125121 (2017). [3] H. C. Wu, et al., PRB in print (2019).

MA 59.36 Fri 9:00 P2/EG

All-Optical Magnetoelectric Memory — •Jakub Vít[1], Alexej Pashkin[2], Vilmos Kocsis[3], Yasujiro Taguchi[4], István Kézsmárki[5], and Sándor Bordács[1] — [1]Budapest University of Technology, Hungary — [2]HZDR Dresden, Germany — [3]IFW Dresden, Germany — [4]RIKEN, Japan — [5]Uni Augsburg, Germany

We demonstrated feasibility of magnetoelectric domain selection by the intense electromagnetic radiation of the FELBE Free Electron Laser. Our experiments showed that among the two magnetic domains, one can be selected in a $LiCoPO_4$ single crystal cooled from the paramagnetic to the antiferromagnetic phase while it was irradiated by the FELBE. The FELBE was the most efficient when 1) its frequency was tuned close to the ME mode at 1.35 THz, 2) the cooling rate was low, and 3) the FEL power was the maximum. In this poster, I discuss possible mechanisms causing domain imbalance.

MA 59.37 Fri 9:00 P2/EG

Dimerization in the commensurate antiferromagnetic phase of $MnWO_4$ and $NaFe(WO_4)_2$ — •Sebastian Biesenkamp[1], Yvan Sidis[2], Navid Qureshi[3], Dmitry Gorkov[1], Karin Schmalzl[4], Wolfgang Schmidt[4], Petra Becker[5], Ladislav Bohatý[5], and Markus Braden[1] — [1]Institute of Physics II, University of Cologne — [2]Laboratoire Léon Brillouin, CEA-CNRS, CEA/Saclay — [3]ILL, Grenoble — [4]JCNS at ILL, Grenoble — [5]Sect. Crystallography, Institute of Geology and Mineralogy, University of Cologne

In multiferoic $MnWO_4$, the relaxation time of the multiferroic domain inversion shows a peculiar temperature dependence. Upon cooling below the multiferroic transition the relaxation time first increases but becomes faster closer to the commensurate low-temperature phase [1]. We investigated anharmonicities in this material as well as in isostructural $NaFe(WO_4)_2$ and propose the enhanced anharmonicities close to the low-temperature magnetic up-up-down-down structure to be responsible for the faster relaxation rates in $MnWO_4$. In both materials there is a similar competition between incommensurate cycloid and commensurate up-up-down-down order, and anharmonic squaring up appears as a precursor in the incommensurate structure [2]. The commensurate magnetic structure is associated with structural dimerization in both materials, that has been quantitatively determined for $NaFe(WO_4)_2$ by a four-circle neutron diffraction experiment. [1]: M. Baum, Phys. Rev. B 89, 144406 (2014) [2]: S. Holbein, Phys. Re. B 94, 104423 (2016)

MA 59.38 Fri 9:00 P2/EG

Direct comparison of magnetization reversal loops and

anomalous Hall resistivity loops of ultra-thin $SrRuO_3$-heterostructures — G. Malsch[1], •D. Ivaneiko[1], P. Milde[1], L. Wysocki[2], L. Yang[2], P. H.M. van Loosdrecht[2], I. Lindfors-Vrejoiu[2], and L. M. Eng[1,3] — [1]Institute for Applied Physics, TU Dresden, 01062 Dresden, Germany — [2]II. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany — [3]ct.qmat, Dresden-Würzburg Cluster of Excellence - EXC 2147, TU Dresden, 01062

Recently, it was proposed that ultrathin epitaxial layers of $SrRuO_3/SrIrO_3$ heterostructures might host magnetic skyrmions. In such thin films unit, skyrmions usually arise due to broken inversion symmetry at interfaces. The resultant interfacial Dzyaloshinskii-Moriya interaction was predicted to become sizeable through large spin-orbit coupling of the transition metals Ru and Ir. The presence of skyrmions is commonly indirectly proven through macroscopic magneto-transport measurements, then indicating the topological nature through hump-like anomalies observed in the Anomalous Hall effect (AHE) resistivity loops. Here, we investigate the structural and magnetic properties of a 4uc-SRO/2uc-SIO heterostructure comparing their physical properties by measurements with various techniques such as MOKE, AHE transport measurements, nc-SFM and MFM. As a result, we prove that local variations within the 4uc-SRO/2uc-SIO layer cause variations in the local switching fields that are the origins of the hump-like anomalies observed in AHE.

MA 59.39 Fri 9:00 P2/EG

Quasiparticle decay induced by spin anisotropies in the frustrated spin ladder system $BiCu_2PO_6$ — •Leanna Müller and Götz S. Uhrig — TU Dortmund

The inorganic compound $BiCu_2PO_6$ contains tubelike structures, which are described magnetically by weakly coupled frustrated spin ladders with a finite gap. The elementary excitations are triplons of which the degeneracy is lifted due to Dzyaloshinskii-Moriya interactions. In certain regions of the Brillouin zone the lifetime of the triplon excitation modes becomes finite due to hybridization of the single-triplon state with two-triplon states. In addition, the dispersions of these triplon modes show peculiar a down-bending before ceasing to exist. In experiment, $BiCu_2PO_6$ shows various types of decay processes, which can be caused by different symmetry breaking interactions. In previous studies, we established a minimal model to include all symmetry-allowed interactions, such as the Dzyaloshinskii-Moriya interaction. Based on this minimal model, we show that isotropic and anisotropic effects are responsible for noticeable quasiparticle decay and certain down-shifts of the single triplon energies. The analyses are based on a deepCUT approach to the isotropic case augmented by a perturbative treatment of the couplings inducing quasiparticle decay at zero temperature.

MA 59.40 Fri 9:00 P2/EG

Calculation of atomistic magnetic interaction parameters in Pb_2MnO_4 from ab-initio — •Roman Kováčik, Ivetta Slipukhina, Marjana Ležaić, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

For an antiferromagnetic Pb_2MnO_4 material [1], with a potential to exhibit complex magnetic textures, we calculate the ground state electronic structure employing the full-potential Korringa-Kohn-Rostoker Green function method [2]. The symmetric Heisenberg and antisymmetric Dzyaloshinskii-Moriya interaction (DMI) exchange parameters are evaluated using the method of infinitesimal rotations [3] and the site-resolved magnetocrystalline anisotropy (MCA) is obtained from the band energy terms. The large leading DMI parameter relative to the Heisenberg exchange as well as the non-trivial single-site MCA are consistent with the experimentally observed non-collinear spin state. Further detailed analysis of the calculated magnetic interaction parameters will be presented. Support from JARA-HPC (jara0182) and DFG (SFB 917) is gratefully acknowledged.

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[2] N. Papanikolaou *et al.*, J. Phys. Condens. Matter 14, 2799 (2002), also see: jukkr.fz-juelich.de.
[3] A. I. Liechtenstein *et al.*, J. Magn. Magn. Mater. 67, 65 (1987).

MA 59.41 Fri 9:00 P2/EG

Combined theoretical and experimental investigation of the novel $S = 1$ spin dimer system $K_2Ni(MoO_4)_2$ — •Benjamin Lenz[1,2], Swarup K. Panda[3,2], Silke Biermann[2,4], Bommisetti Koteswara Rao[5,6,7], Rao Kumar[8], Panchanana Khuntia[9], Avinash V. Mahajan[8], Michael Baenitz[9], Kee Hoon Kim[10], and Fang-Cheng Chou[7] — [1]IMPMC, Sorbonne Université, Paris, France — [2]CPHT, Ecole Polytechnique, Palaiseau, France — [3]Bennett University, Greater Noida, Uttar Pradesh, India — [4]Collège de France, Paris, France — [5]IIT Tirupati, Tirupati, India — [6]University of Hyderabad, Hyderabad, India — [7]National Taiwan University, Taipei, Taiwan — [8]IIT Bombay, Mumbai, India — [9]MPI-CPS, Dresden, Germany — [10]Seoul National University, Seoul, South Korea

Spin dimer systems have raised a lot of interest in recent years due to the possibility of studying the Bose-Einstein condensation of their magnetic excitations.
Here, we investigate the novel quantum magnet $K_2Ni(MoO_4)_2$, which has been synthesized recently, by means of different state-of-the-art techniques. Measurements and first principles calculations both establish a S=1 spin dimer ground state of the compound and allow to study its magnetic and thermodynamic properties. Using mean-field theory and quantum Monte Carlo simulations we find the magnetization curve, magnetic susceptibility and specific heat in good agreement with recent experiments.
Our results render this novel quantum magnet a promising candidate for the condensation of magnons under an applied magnetic field.

MA 59.42 Fri 9:00 P2/EG

Phase diagram and linearized dynamics of the classical-spin Kondo model on the triangular lattice — •Michael Lau and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

We study the ground-state phase diagram and the linearized real-time dynamics of the Kondo model with classical spins on the half-filled magnetically frustrated two-dimensional triangular lattice. The phase diagram is obtained via a novel technique using an (unphysical) Gilbert damping term to approach the ground state by solving the coupled equations of motion for the classical spins and the reduced one-particle density matrix of the conduction-electron system with a high-order Runge-Kutta method.

We find the classical noncollinear 120° phase in the regime of strong Kondo coupling J as reflected in the spin-structure factor for the classical as well as for the quantum spin-spin correlations by strong peaks at the K-points. At intermediate J, there is a first-order phase transition to a collinear zigzag phase, which exhibits a threefold rotational degeneracy as is again nicely reflected in the spin-structure factor.

The phase diagram sets the stage for subsequent analytical and numerical studies of the real-time dynamics. We compare the full solution of the (physical) equations of motion with the linearized variant in the limit of small excitation energies and study the dispersions of the Goldstone modes and the linearized dynamics close to the critical point.

MA 59.43 Fri 9:00 P2/EG

Temperature dependent, spin-resolved measurements of the electronic structure of Gd — •Josef Ketels[1], Michael Leitner[2], and Christoph Hugenschmidt[1,2] — [1]Physik Department E21, Technische Universität München, 85748 Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, 85748 Garching, Germany

The ferromagnetic rare earth metal gadolinium crystallizes in the hexagonal closed package structure. It is the only rare earth metal ordering ferromagnetically near room temperature with a Curie temperature of 294 K. At $T_{SR} \approx 230$ K a spin reorientation transition occurs, turning the magnetic moment axis away from the c-axis below T_{SR} [1]. The measurement of the two dimensional angular correlation of positron annihilation radiation (2D-ACAR) is a powerful tool to investigate the bulk electronic structure. Based on the spin-polarization of the positrons from a ^{22}Na source, the minority and majority spin-channels can be determined separately. We present recent temperature dependent and spin-resolved 2D-ACAR measurements on Gd, probing the electronic structure at 0 K, 260 K and 305 K.

[1] J. W. Cable and E. O. Wollan, Phys. Rev. 165, 733 (1968)

MA 59.44 Fri 9:00 P2/EG

Exotic magnetism in novel $RE_3Fe_3Sb_7$ compounds — •S. Palazzese[1], S. Chattopadhyay[1], M. Uhlarz[1], S. Yamamoto[1], F. Pabst[3], T. Herrmannsdörfer[1], J. Wosnitza[1,2], and M. Ruck[3] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf — [2]Institut für Festkörper-und Materialphysik, TU Dresden — [3]Fakultät für Chemie und Lebensmittelchemie, TU Dresden

Here we present a DC magnetization study of novel $RE_3Fe_3Sb_7$ (RE = Pr, Nd, Sm) compounds with hexagonal crystalline structure $P6_3/m$. Measurements are performed at temperatures from 2 to 400 K and fields up to 7 T by means of SQUID magnetometry on single crystals. We observe a plethora of magnetic phase transitions at temperatures below 390 K. We show that the B-T phase diagram varies with the chemical RE composition of the compound and anisotropic magnetic behavior is observed for different orientations. Below 20 K, we observe a wide magnetic hysteresis loop, while at higher temperatures soft-magnetic behavior is found. Our results suggest strong evidence for the occurence of ferrimagnetic compensation points for each compound.

MA 59.45 Fri 9:00 P2/EG

Topological excitations in the Shastry-Sutherland model compound $SrCu_2(BO_3)_2$ — •Dirk Wulferding[1,2], Peter Lemmens[1,2], Youngsu Choi[3], Kwang-Yong Choi[3], and Hiroshi Kageyama[4] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]Chung-Ang Univ., Seoul, Korea — [4]Chemistry Dept., Kyoto Univ., Japan

In the Shastry-Sutherland model compound $SrCu_2(BO_3)_2$ the ground state is composed of orthogonal spin dimers with low-energy triplon excitations and bound states [1]. In applied magnetic fields of around 1.4 T a topological phase transition is induced, where magnon bands acquire a finite Chern number together with the formation of topologically protected edge states [2,3] - realizing a magnetic analogue of a topological insulator. At higher fields around 27 T a 1/8 magnetization plateau corresponding to the crystallization of triplons appears [4]. Our Raman spectroscopic study at low and high magnetic fields probes the magnetic excitations in the singlet sector through the topological phase transitions. Work supported by QUANOMET NL-4 and DFG LE967/16-1. [1] P. Lemmens, et al., Phys. Rev. Lett. 85, 2605 (2000). [2] J. Romhanyi, et al., Nat. Commun. 6, 6805 (2015). [3] P. A. McClarty, et al., Nat. Phys. 13, 736 (2017). [4] H. Kageyama, et al., Phys. Rev. Lett. 82, 3168 (1999).

MA 59.46 Fri 9:00 P2/EG

Quantum criticality in α-$RuCl_3$ investigated by means of dilatometry — •Vilmos Kocsis[1], Anja U.B. Wolter[1], Sebastian Gass[1], Laura T. Corredor[1], Pedro M. Consoli[2,3], Lukas Janssen[2], Matthias Vojta[2], Paula L. Kelley[4,5], Stephen Nagler[6], David G. Mandrus[4,5], and Bernd Büchner[1,7] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Germany — [2]Institute for Theoretical Physics, Technical University Dresden, Germany — [3]Instituto de Física de Sao Carlos, Universidade de Sao Paulo, Sao Carlos, Brazil — [4]Materials Science and Engineering Department, University of Tennessee, USA — [5]Materials Science and Technology Division, Oak Ridge National Laboratory, USA — [6]Neutron Scattering Division, Oak Ridge National Laboratory, USA — [7]Institute of Solid State and Materials Physics, Technical University Dresden, Germany

When the antiferromagnetic zigzag phase is suppressed, field-induced quantum criticality was found around B_c 7-8T in the quantum spin liquid candidate α-$RuCl_3$ [1]. We present high-resolution thermal expansion α, magnetostriction λ, and specific-heat (C_p) measurements on α-$RuCl_3$. The extracted Grüneisen parameter $\Gamma = \alpha/Cp$ shows divergence as typical for quantum critical behavior. Our thermodynamic experiments further hint at the existence of a third low-temperature phase in the examined field range in general agreement with former magnetocaloric and neutron diffraction measurements [2]. [1] A. U. B. Wolter et. al., PRB 96, 041405(R) (2017) [2] Christian Balz et al., Phys. Rev. B 100, 060405(R) (2019).

MA 59.47 Fri 9:00 P2/EG

Domain-Superconductivity in Nb/FePd with lateral inhomogeneous magnetization — •Annika Stellhorn[1], Anirban Sarkar[1], Emmanuel Kentzinger[1], Sonja Schröder[1], Grigol Abuladze[1], Markus Waschk[1], Tanvi Bhatnagar[1,2], Patrick Schöffman[3], Zhendong Fu[3], Vitaliy Pipich[3], Kathryn Krycka[4], Juri Barthel[5], and Thomas Brückel[1,3] — [1]Forschungszentrum Jülich GmbH, JCNS-2 and PGI-4, JARA-FIT, Jülich, GERMANY — [2]Forschungszentrum Jülich GmbH, PGI-5, Jülich, GERMANY — [3]Forschungszentrum Jülich GmbH, JCNS@MLZ, Garching, Germany — [4]NIST Center for Neutron Research, NIST, Gaithersburg, USA — [5]Forschungszentrum Jülich GmbH, ER-C 2, Jülich, Germany

We aim at understanding the proximity effects in the superconductor-ferromagnet (S/F) interface of Nb(S)/FePd(F) thin film heterostructures, prepared by MBE growth. Proximity effects at S/F interfaces with an inhomogeneous magnetic field texture result in various effects, like domain-wall superconductivity. To reveal the physical origin of each effect, we compare samples with S/F in direct proximity and S/F decoupled by a thin MgO layer. Measurements of the resistivity and magnetization show striking differences in their critical temperature and the critical field values. According to our results, we ascribe the observed domain-wall and reverse-domain superconductivity to the long-range magnetic interactions. Using polarized neutron scattering techniques, we focus on revealing the lateral magnetic depth profile of the heterostructures as function of temperature.

MA 59.48 Fri 9:00 P2/EG

$CrI_3/NbSe_2/CrI_3$ van der Waals heterostructure: Superconducting spin-valve? — •Chandan K Singh[1] and Mukul Kabir[1,2] — [1]Department of Physics, Indian Institute of Science Education and Research, Pune, India — [2]Center for Energy Science, Indian Institute of Science Education and Research, Pune, India

The proximity of ferromagnetic insulator (FI) and superconductor (S) has attracted the scientific community because of its rich physics and the influence of ferromagnet on the superconductor. Within the first-principles calculations, here we investigate the van der Waals heterostructure of $NbSe_2$ a two-dimensional (2D) superconductor and monolayer CrI_3 a 2D ferromagnetic insulator. Results indicate that magnetism is induced in the $NbSe_2$ layer while the moments in the CrI_3 layers ferromagnetically align. The magnetic moment developed at the Nb-sites decay to zero for antiparallel spin configuration in the CrI_3 layers. Further, we discuss the effects on the metallicity in the $NbSe_2$ layer concerning the relative spin order in the CrI_3 layers and discuss the survival of Ising spin-orbit coupling and nodal topological superconductivity in the $NbSe_2$. These results confirm the theoretical predictions by de Gennes for the thin-film FI/S/FI systems and also indicate the $CrI_3/NbSe_2/CrI_3$ van der Waals heterostructure a possible candidate for superconducting spin-valve.

MA 59.49 Fri 9:00 P2/EG

Large Uniaxial Magnetic Anisotropy of hexagonal Fe-Hf-Sb Alloys — •Maxim Tchaplianka[1], Lukáš Kývala[1,2], Alexander Shick[1], Sergii Khmelevskyi[3], and Dominik Legut[2] — [1]Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic — [2]IT4Innovations and Nanotechnology Centre, VSB - Technical University of Ostrava, Ostrava-Poruba, Czech Republic — [3]Center for Computational Materials Science, Vienna University of Technology, Vienna, Austria

Chemical engineering of the magnetic anisotropy in ferromagnets via element substitution is a promising method of creating permanent magnets. Recent experiments have shown that antimony substitution into Fe_2Hf produces an alloy with the large positive magnetic anisotropy energy necessary for permanent magnets[1]. We investigate the electronic and magnetic properties of Laves phase hexagonal Fe_2Hf and Fe-Hf-Sb alloys making use of the density functional theory. The magnetic moments on individual atoms and the total and projected densities of states are calculated. Fe_2Hf is shown to be metallic and ferrimagnetic with an easy-plane preferential direction. Antimony substitution is found to suppress the planar magnetization direction and favor the uniaxial magnetic anisotropy, in agreement with experimental observations.

[1] D. Goll et al., *Hard Magnetic Off-Stoichiometric $(Fe,Sb)_{2+x}Hf_{1-x}$ Intermetallic Phase.* Phys. Status Solidi RRL, **11**, 1700184 (2017).

MA 59.50 Fri 9:00 P2/EG

Influence of the rapid cooling parameters in an adapted melt spinning process on microstructure and magnetic properties of Nd-Fe-B strip cast alloys — •Franziska Staab, Corinna Müller, Stefan Riegg, and Oliver Gutfleisch — TU Darmstadt, Materialwissenschaft, Alarich-Weiß-Str. 16, 64287, Darmstadt, Germany

High-performance Nd-Fe-B magnets are a main component of the power train in e-mobility. The production of the magnets is based on a powder metallurgical route, for which in the first step strip cast (SC) flakes are produced. The rapid cooling during the SC process results in a microstructure which essentially determines the quality of subsequent production steps such as hydrogen decrepitation, jet milling as well as sintering. A control of the microstructure evolution leads to enhanced magnetic properties of the final magnets. Since the minimum amount of material processed with SC is in the range of 20-50 kg and thus very costly, we investigate the influence of different cooling conditions and additional alloying elements on the microstructure with an own modified setup in a melt-spinner. A typical industrial relevant alloy composition of $(Nd,Pr,Dy,Tb)_{14,6}Fe_{77,9}(Co,Cu,Al,Ga)_{1,7}B_{5,8}$ was used to study the influence of the processing parameters before further elements were added. Scanning electron microscopy reveals a similar microstructure of the melt spun ribbons compared to the strip cast flakes. A detailed characterization and discussion of microstructure and magnetic properties are presented.

MA 60: Magnetic Coupling and Anisotropy in Thin Films (joint session MA/DS)

Time: Friday 9:30–13:00 Location: HSZ 04

MA 60.1 Fri 9:30 HSZ 04

Imaging of ultrafast spin dynamics using high-harmonic radiation — •Sergey Zayko[1], Ofer Kfir[1], Michael Heigl[2], Michael Lohmann[1], Jakob Hagen[1], Murat Sivis[1], Manfred Albrecht[2], and Claus Ropers[1] — [1]IV Physical Institute, University of Göttingen — [2]Experimental physics IV, University of Augsburg

The demand for next-generation information processing methodologies increases the interest in spintronic devices, as they may offer energy-efficient operation at THz frequencies [1,2]. Such developments require means for tracking of magnetic dynamics with nanoscale resolution and a temporal precision well below a picosecond, as highlighted in a first experimental effort [3]. Here we utilize MCD (magnetic circular dichroism) imaging with high-harmonic radiation [4] for the mapping of spin-texture dynamics. Our experiment captures magnetic movies with a combined 40 nm spatial- and 40 femtosecond temporal resolutions, and images with resolution better than 20 nm. We use these capabilities to follow the ultrafast responses of magnetic domains in materials with perpendicular magnetic anisotropy, such as local ultrafast demagnetization and non-local dynamics near domain walls. We believe that our approach will yield deeper insights into the corresponding physics of the ultrafast magnetism and become an indispensable tool for applied research.

[1] A. Fert, V. Cros, and J. Sampaio, Nat Nano 8, 152 (2013). [2] Nature Nanotech 10, 185 (2015). [3] C. von Korff Schmising et al., Phys. Rev. Lett. 112, 217203 (2014). [4] O. Kfir, S. Zayko et al., Science Advances 3, eaao4641 (2017).

MA 60.2 Fri 9:45 HSZ 04

Complex spin textures and domain-wall pinning in Sm-Co magnets — Leonardo Pierobon[1], András Kovács[2], Robin E. Schäublin[1], Stephan S. A. Gerstl[1], Urs Wyss[3], •Jan Caron[2], Rafal E. Dunin-Borkowski[2], Jörg F. Löffler[1], and Michalis Charilaou[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, Switzerland — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, FZ Julich, Germany — [3]Arnold Magnetic Technologies, Switzerland

Sm-Co alloys are the best-performing permanent magnets at high temperatures due to their cellular microstructure, which consists of a Sm2Co17 matrix and SmCo5 cells intersected by Zr-rich platelets. Although extensive research has been done to understand the connection between the magnet's microstructure and its magnetic properties, theory and experiments have still not converged. To tackle this issue, we use Lorentz transmission electron microscopy, off-axis electron holography and micromagnetic simulations. We find that the magnetization reversal starts by domain-wall nucleation at the interfaces between Zr-rich platelets and the Sm2Co17 matrix. Despite strong pinning at the SmCo5 cells, curling instabilities form where all three phases meet, further propagating the reversal. Unexpectedly, we also find topologically non-trivial structures with 2π winding that significantly affect the reversal. Based on this, we propose a modification of microstructure to increase the coercivity and remanence.

MA 60.3 Fri 10:00 HSZ 04

Titanium d-ferromagnetism with perpendicular anisotropy in defective anatase — •Markus Stiller[1], Alpha T. N'Diaye[2], Hendrik Ohldag[2], José Barzola Quiquia[1], Pablo D. Esquinazi[1], Thomas Amelal[3], Carsten Bundesmann[3], Daniel Spemann[3], Martin Trautmann[4], Angelika Chassé[4], Hichem Ben Hamed[4], Waheed A. Adeagbo[4], and Wolfram Hergert[4] — [1]Felix-Bloch-Institute for Solid-state Physics, University of Leipzig, Germany — [2]ALS, Lawrence Berkeley National Laboratory, USA — [3]Leibniz Institute of Surface Engineering, Germany — [4]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Germany

Undoped TiO2 anatase thin films were grown on LAO and STO substrates. Ferromagnetism was generated at the surface of anatase films by low-energy ion irradiation. Ar+-ion irradiation resulted in a thin (10nm) ferromagnetic surface layer. Field hysteresis as well as zero-field cooled and field cooled curves reveal that, after irradiation the samples show ferromagnetism at room temperature with an out-of-plane easy axis and low remanence. Magnetic force microscopy reveals that this low remanence is due to oppositely aligned magnetic domains. XMCD measurements at room temperature show that the band at the titanium L-edges is spin polarized, not at the O K-edge. Together with DFT calculations, the results indicate that Ti vacancy-interstitial pairs are responsible for the magnetic order. These results open up interesting possibilities for future applications, e.g. single domain patterns of μm size can be easily prepared. Further, they contradict the theory of paramagnetism due to vacuum fluctuations proposed by Coey.

MA 60.4 Fri 10:15 HSZ 04

Magnetic anisotropy of disordered FeRh thin films probed by X-band ferromagnetic resonance — •Jonas Wiemeler[1], Anna Semisalova[1], Benjamin Zingsem[1], Nicolas Josten[1], Ralf Meckenstock[1], Rantej Bali[3], Kay Potzger[3], Jürgen Lindner[3], Jürgen Fassbender[3], Thomas Thomson[2], and Michael Farle[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]The University of Manchester, UK — [3]Institute of Ion Beam Physics and Materials Research, HZDR, Germany

The ion irradiation induced disorder in FeRh thin films changes certain magnetic properties, such as phase transition temperature from AF to FM states and saturation magnetisation. Furthermore, the free energy density changes correspondingly to the magnetocrystalline anisotropy variation in irradiated films. Here, ferromagnetic resonance (FMR) experiments were carried out to analyse the magnetic anisotropy of 25 keV Ne^+-irradiated 40 nm thick $Fe_{50}Rh_{50}$ films. A total of 6 films, irradiated with an ion fluence of $1 \cdot 10^{13} - 4 \cdot 10^{14}\ \frac{\text{Ions}}{\text{cm}^2}$, were characterised with FMR at 100 - 400 K and compared with a non-irradiated film.

The anisotropy of Ne-irradiated FeRh thin film changes from cubic for a low ion fluence to a mixture of cubic and in-plane uniaxial anisotropy, the latter contribution turns out to be dominating for higher fluence. The sign of the perpendicular magnetic anisotropy constant $K_U = K_{2\perp}$ was found to reverse while Ne^+ fluence is increasing. Supported by DFG SE2853/1-1, BA5656/1-1.

MA 60.5 Fri 10:30 HSZ 04

Ferromagnetic writing on B2 $Fe_{49}Rh_{51}$ thin films using ultra-short laser pulses — •Alexander Schmeink[1,2], Benedikt Eggert[3], Jonathan Ehrler[1], Mohamad-Assaad Mawass[4], René Hübner[1], Kay Potzger[1], Jürgen Lindner[1], Jürgen Fassbender[1,2], Florian Kronast[4], Heiko Wende[3], and Rantej Bali[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Fakultät für Physik, Technische Universität Dresden, Germany — [3]Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Germany — [4]Helmholtz-Zentrum Berlin, Germany

Laser manipulation of magnetic properties has potential applications in data storage. The equiatomic B2 FeRh alloy is well-known to show a metamagnetic isostructural antiferromagnetic (AFM) to ferromagnetic (FM) transition at $\approx$370 K. In contrast to the temperature-driven transition an AFM B2 $\rightarrow$ FM B2 transition can be induced via a decrease of short-range atomic order, which can be realised in alloy thin films using ion beams as well as laser pulses.[1]

Here we irradiate B2 $Fe_{49}Rh_{51}$ thin films of $\leq$30 nm thicknesses with $\sim$100 fs laser pulses and observe the induced magnetic and structural changes. Depending on the laser fluence transitions of AFM to FM B2 $Fe_{49}Rh_{51}$ and with further disordering to the paramagnetic A1 structure are observed. The deposited energy influences the resolidifcation of the alloy, thereby determining the structure.

This work is funded by the DFG (BA 5656/1-1 and WE 2623/14-1).

[1] J. Ehrler et al. *ACS Applied Materials & Interfaces* **2018** 10 (17), 15232-15239

MA 60.6 Fri 10:45 HSZ 04

Magnetic structure and coupling phenomena of DyCo alloys — •Dieter Lott[1], Kai Chen[2], André Philippi-Kobs[3], and Valeria Lauter[4] — [1]Institute of Material Research, Helmholz-Zentrum Geesthacht, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany — [4]Neutron Scattering Division, Neutron Sciences Directorate, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

In the last years, alloys of rare-earth elements and 3d transition metals (RE-TM) became again in the focus of attention due there rich variety of magnetic effects owed to the different anisotropies of both material classes. Despite of their amorphous composition, this material class exhibits complex magnetic ordering resulting into non-collinear spin structures and the occurrence of magnetic chirality effects. Lately, different exchange bias phenomena were discovered in DyCo single films and in heterostructures [1,2]. In a very recent study, the occurrence of skyrmions in a single DyCo film could be observed. The analysis of the magnetic microstructure is one of the important keys for understand the underlying mechanism behind these intriguing phenomena. In this work, we report recent results on DyCo/NiFe thin films investigated via polarized neutron reflectometry. The analysis of the magnetic and chemical depth profiles at different magnetic fields and temperature allows one to gain insights into the coupling mechanism in these heterostructures.

15 min. break.

MA 60.7 Fri 11:15 HSZ 04

Crystallographic and magnetic structure in Co thin films investigated by NMR — •Patrizia Fritsch[1], Juriaan Lucassen[2], Casper F. Schippers[2], Marcel A. Verheijen[2,3], Erik J. Geluk[4], Beatrice Barcones[4], Rembert A. Duine[2,5], Henk J. M. Swagten[2], Bert Koopmans[2], Reinoud Lavrijsen[2], and Sabine Wurmehl[1,6] — [1]IFW Dresden, Germany — [2]Department of Applied Physics, TU Eindhoven, the Netherlands — [3]Eurofins Materials Science, Eindhoven, the Netherlands — [4]NanoLab@TU/e, TU Eindhoven, the Netherlands — [5]Institute for Theoretical Physics, Utrecht University, the Netherlands — [6]Institute of Solid State and Materials Physics, TU Dresden, Germany

Co thin films sandwiched between Pt and Ir (Pt (4 nm) / Co (t) / Ir (3 nm)) with t = 5 - 25 nm were grown. These films showed an increase in the out of plane (oop) magnetic anisotropy constant K above a critical thickness t_{cr}. The increase in the anisotropy K is linked to the formation of hcp Co on top of fcc Co due to lattice relaxation with increasing thickness t. We measured two films with Co thicknesses t = 10 nm $> t_{cr} > t$ = 25 nm by means of ^{59}Co zero-field nuclear magnetic resonance spectroscopy (ZF NMR) exploiting the internal field of the ferromagnetic material. ZF NMR is sensitive to changes in the local crystallographic and magnetic environment. In this contribution we will explain the overall increase of the anisotropy K due to magnetocrystalline (intrinsic) and magnetoelastic (extrinsic) effects on the basis of the ^{59}Co ZF NMR data.

MA 60.8 Fri 11:30 HSZ 04

Magneto-optical signal dependence on Co-layer thickness asymmetry in Co/Pt/Co-films — •Ramon Weber[1], Carmen Martín Valderrama[1,2], Lorenzo Fallarino[1], and Andreas Berger[1] — [1]CIC nanoGUNE, E-20018 Donostia-San Sebastian, Spain — [2]Faculty of Science, University of Valladolid, E-47011 Valladolid, Spain

Ever since the first observation of interlayer exchange coupling, magnetic multilayers have been a research subject of tremendeous importance, leading to many surprising phenomena. In a recent study, Tomita *et al.* [1] observed a most significant enhancement of the magneto-optical response in Fe/Pt multilayers that followed an inverse Fibonacci thickness stacking in comparison to periodically modulated reference samples. This effect could not be explained by classical electromagnetic theory assuming local material dependent dielectric properties, but might be related to quantum mechanical interferences associated with non-periodic stacking of nm-scale magnetic films and their resulting quantum well states. To test this explanation, we fabricated a series of Co/Pt/Co bilayer structures with pre-defined and variable thickness asymmetry of the Co layers, while keeping the total Co thickness constant. The optical and magneto-optical properties of these films were measured using Generalized Magneto-optical Ellipsometry, both as a function of the Co-layer thickness asymmetry and the Pt interlayer thickness.

[1] S. Tomita, T. Suwa, P. Riego, A. Berger, H. Nobuyoshi, and H. Yanagi, Phys. Rev. Appl. 11, 064010 (2019).

MA 60.9 Fri 11:45 HSZ 04

Interlayer exchange coupling in Fe/MgO[001] multilayers — •Tobias Warnatz[1], Fridrik Magnus[2], Sarah Sanz[1], Hasan Ali[3], Klaus Leifer[3], and Björgvin Hjörvarsson[1] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Science Institute, University of Iceland, Reykjavik, Iceland — [3]Department of Engineering Sciences, Uppsala University, Sweden

Fe/MgO/Fe tunnel junctions are well known for their magnetoresistance, but their interlayer exchange coupling (IEC) [1] is less explored. Recently, we reported a sequential magnetic switching in interlayer exchange coupled Fe/MgO[001] superlattices [2]. The presented results were consistent with a beyond nearest neighbor IEC. Here, we report the first systematic investigation on the range of IEC in epitaxial Fe/MgO[001] multilayers. For that, samples with various Fe/MgO bilayer repetitions (N) were grown on single crystalline MgO(001) substrates. Hystereses curves with discrete magnetization steps were obtained, consistent with our previous results [2]. Taking only nearest-neighbor interactions into account, a reduction of the IEC by a factor of (1-1/N) should be observed [3] (the missing neighbor of the outermost layers becomes less important for many N). Our results deviate drastically from this prediction and verify a strong contribution from beyond nearest neighbor interactions. The results are essential for the understanding of the IEC in tunnel junctions and could even serve as a base for the development of three-dimensional data structures.

[1] Phys. Rev. Lett. 89, 106602 (2002) [2] Phys. Rev. B 97, 74424 (2018) [3] Appl. Phys. Lett. 58, pp. 1473-1475 (1991)

MA 60.10 Fri 12:00 HSZ 04

Probing the origin of ferromagnetic stability in LSMO/SRO — •Anna Zakharova — Swiss Light Source, Paul Scherrer Institut

The technological application of optimally doped mangnite is hindered due to the existence of a magnetic dead layer. However, when in contact with $SrRuO_3$ $La_{0.7}Sr_{0.3}MnO_3$ remains magnetic down to 1-2 u.c. Therefore in this work we investigate the origin of the ferromagnetic stability of LSMO in LSMO/SRO bilayers by using resonant x-ray spectroscopy varying thickness of LSMO and SRO deposited on $SrTiO_3$. Magnetic switching of LSMO in proximity with 20 u.c. SRO was observed even below critical thickness of LSMO. Moreover, 4 u.c. of LSMO shows remanence above SRO T_c. The XLD data evidences a preferential $d3z^2 - r^2$ occupation of Mn in LSMO/SRO interface in agreement with theoretical predictions. In addition, different Mn valence is observed for ultra-thin LSMO/SRO in comparison to LSMO//STO. These results combined can explain why the ferromagnetism is stabilized at LSMO/SRO interface.

MA 60.11 Fri 12:15 HSZ 04

Influence of structure and cation distribution on magnetic anisotropy and damping in Zn/Al doped nickel ferrites — •Julia Lumetzberger, Martin Buchner, Santa Pile, Verena Ney, and Andreas Ney — Johannes Kepler University Linz, Institute for Semiconductor and Solid State Physics, Linz, Austria

In spintronics one aims to obtain pure spin currents as an additional degree of freedom. To ensure a pure spin component ferromagnetic insulators are the material of choice. Promising results are obtained by cubic NiZnAl ferrite thin films grown on spinel $MgAl_2O_4$[1].In this contribution we use reactive magnetron sputtering as a preparation method to optimise the magnetic properties. All samples are analysed with X-ray diffractometry for their crystallographic properties. Furthermore, the angular and frequency dependence of the resonance position is measured by ferromagnetic resonance (FMR) and fitted to quantify the anisotropy fields as well as magnetic damping. Additionally, transmission electron microscopy is performed to investigate the interface on an atomic scale and the chemical composition by means of ion beam analysis. In a last step x-ray magnetic circular dichroism (XMCD) and XMCD (H) at the $L_{3,2}$ edge of Ni and Fe are performed to complement the integral SQUID magnetometry measurements and evidence their magnetic contributions to the hysteresis separately. A comparison between similarly strained materials revealed the importance of site occupancy as a major tuning factor for magnetic anisotropy and damping [2]. [1] S. Emori et. al., Adv. Mater. (2017), 29, 1701130 [2] J. Lumetzberger, arXiv:1908.08257 (2019)

MA 60.12 Fri 12:30 HSZ 04

Artificial bulk metamaterials based on graded epitaxial Co-alloy films — •Lorenzo Fallarino, Mikel Quintana, Ramon Weber, and Andreas Berger — CIC nanoGUNE, 20018 Donostia-San Sebastian, Basque Country, Spain

A very promising alternative to traditional magnetic information storage is based upon encoding information via non-collinear magnetic textures. They occur in certain materials with structure inversion asymmetry, a property that in conjunction with spin-orbit coupling leads to the Dzyaloshinskii-Moriya interaction (DMI). At interfaces between magnetic layers and heavy metals the DMI can be strong enough to promote non-collinear spin textures as ground states [1]. However, any real multilayer is prone to growth induced imperfections at each interface that can strongly affect the energetic landscape. Likewise, interfaces are the only portions that can be influenced in such multilayers, inherently limiting the total active contributions to a small fraction of an entire structure. Along these lines, we have devised an innovative approach by means of artificial bulk metamaterials $Co_{1-x}A_x$ (with A = Ru, Pt, Cr) exhibiting pre-defined graded composition structures, allowing for an expansion of DMI generating interfaces into the entirety of the material, thus enabling all-interface-bulk metamaterial. [1] A. Fert, N. Reyren, and V. Cros, Nat. Rev. Mat. 2, 17031 (2017).

MA 60.13 Fri 12:45 HSZ 04

Growth, structure, and magnetic properties of artificially layered NiMn in contact to ferromagnetic Co on $Cu_3Au(001)$ — •Tauqir Shinwari[1], Ismet Gelen[1], Melek Villanueva[2], Yasser A. Shokr[1,3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Division of Permanent Magnets and Applications, IMDEA Nanoscience, 28049, Madrid, Spain — [3]Faculty of Science, Department of Physics, Helwan University, 17119 Cairo, Egypt

A series of experiments is carried out to identify the fundamental mechanisms leading to the exchange-bias effect in ultrathin epitaxial layered ferromagnetic/antiferromagnetic (FM/AFM) samples on $Cu_3Au(001)$. The studied samples are single-crystalline antiferromagnetic artificially layered [Ni/Mn] films covered by ferromagnetic Co layers, deposited under ultrahigh-vacuum conditions. The approach is to study the structural and magnetic properties of artificially ordered layers of Ni and Mn in contact to Co by using low-energy electron diffraction (LEED) and magneto-optical Kerr effect, respectively, and comparing with disordered Ni_xMn_{1-x} alloy films with the same Ni/Mn ratio and the same film thickness. We found from LEED I(V) curves that the perpendicular interatomic lattice distance is decreased in the artificially layered [Ni/Mn] samples in comparison to the disordered Ni_xMn_{1-x} alloy films. This change in the structure causes higher coercivity, exchange bias, and stronger exchange coupling in artificially layered [Ni/Mn] samples compared to disordered Ni_xMn_{1-x} alloy films.

MA 61: Caloric Effects

Time: Friday 9:30–13:15 Location: HSZ 101

MA 61.1 Fri 9:30 HSZ 101

On the exploration of mechanical and magnetic properties of Ni-Mn-In Heusler alloy system doped with Gd — •Wei Liu, Franziska Scheibel, Lukas Pfeuffer, Andreas Taubel, Konstantin Skokov, and Oliver Gutfleisch — Funktional Materials, Technische Universität Darmstadt

NiMn- based Heusler alloys can be used in a six-step multistimuli cooling cycle which combines the magnetocaloric effect and the elastocaloric effect. This multistimuli cooling cycle has been demonstrated to be able to exploit the thermal hysteresis to achieve a fully reversible caloric effect [1]. However, the brittleness of NiMn- based Heusler alloys is problematic for cyclic application with stress. A possible method to strengthen them is precipitation hardening. By doping with Gd we introduced Gd-rich precipitates to the Ni-Mn-In system. With a slight increase of the hysteresis and a slight decrease of the transition steepness, the magnetic entropy change of the doped sample of 9 $J\,kg^{-1}K^{-1}$ can be largely retained, compared to the undoped sample with a value of 11 $J\,kg^{-1}K^{-1}$. An adiabatic temperature change of 4 K is measured in the Gd-doped sample under 2 T, whereas the value for the undoped sample is 5 K. The compressive tests show that the compressive stress is increased by almost 3 times by doping, which is beneficial for the multi-stimuli cooling cycle. The work is supported by the ERC (Project 'Cool Innov') and DFG (Grant No. SPP 1599). [1] T. Gottschall, A. Gràcia-Condal, M. Fries, A. Taubel, L. Pfeuffer, L. Mañosa, A. Planes et al., A multicaloric cooling cycle that exploits thermal hysteresis, Nature materials 17 (2018) 929*934.

MA 61.2 Fri 9:45 HSZ 101

Magnetocaloric materials for multi-stimuli cooling cycle - required functional properties and potential materials — •Franziska Scheibel[1], Tino Gottschall[2], Lukas Pfeuffer[1], Andreas Taubel[1], Dominik Ohmer[1], Konstantin Skokov[1], Bai-Xiang Xu[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt, Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Germany

Materials with a first-order magnetostructural phase transition (FOMST) exhibit a large magnetocaloric effect. However, due to the thermal hysteresis coming along with FOMST the cyclic performance of that materials is limited. The origins of the hysteresis are quite complex but this complexity can also be utilized to tune it [1,2]. So far, a lot of research has been directed towards reducing the hysteresis. Our new cooling concept actually attempts to exploit hysteresis in a multi-stimuli approach [3]. Herein, a second stimulus (uniaxial load) besides the magnetic field stimulus is used to overcome hysteresis and enable a fully reversible FOMST and therefore increase the cyclic performance of the magnetocaloric material. For the multi-stimuli approach a variety of new functional properties are required and we present here a first summary of experimental and theoretical findings on tailored Ni-Mn-X Heusler alloys as potential candidates. This work was supported by the ERC Advanced Grant "Cool Innov" and the SFB-TRR270 "Hommage". [1] O. Gutfleisch et al., Phil. Trans. R. Soc. A 374: 20150308 (2016) [2] F. Scheibel et al., Energy Technol. 6, 1397 (2018) [3] T. Gottschall et al., Nat. Mater. 17, 929 (2018)

MA 61.3 Fri 10:00 HSZ 101

Optimizing the magnetocaloric effect in all-d-metal Ni-Co-Mn-Ti Heusler alloys — •Benedikt Beckmann, Andreas Taubel, Lukas Pfeuffer, Franziska Scheibel, Konstantin Skokov, and Oliver Gutfleisch — Institut für Materialwissenschaft, TU Darmstadt, 64287 Darmstadt, Germany

Magnetocaloric refrigeration is a promising cooling technology which could be an environmentally friendly and more energy efficient alternative to conventional vapor compression refrigeration. Among magnetocaloric materials, Ni-Mn based Heusler alloys, showing a first-order magnetostructural phase transition, are promising candidates. In this study, we carried out a systematic analysis of all-d-metal $Ni_{50-x}Co_xMn_{50-y}Ti_y$ Heusler alloys. Due to their enhanced mechanical stability and large volume change, these alloys could be used for cooling cycles that use magnetic field and pressure as external stimuli for inducing the phase transition. A systematic heat treatment optimization is carried out, resulting in a substantial decrease of the transition width down to only 4 K. The microstructural differences between the as-cast and differently annealed alloys are analyzed in detail by *in-situ* Kerr microscopy. As a result, large isothermal entropy changes of up to 38 $Jkg^{-1}K^{-1}$ in 2 T are achieved. The adiabatic temperature change is measured directly for this material system and values of up to -3.8 K for the first field application and -0.8 K under cyclic conditions are obtained in moderate magnetic field changes of 2 T.

We acknowledge financial support from ERC (Advanced Grant "Cool Innov", No. 743116) and DFG (CRC/TRR 270).

MA 61.4 Fri 10:15 HSZ 101

Time-dependence of the martensitic transformation in Ni-Mn-In Heusler compounds — •Lukas Pfeuffer[1], Tino Gottschall[2], Tom Faske[1], Andreas Taubel[1], Franziska Scheibel[1], Konstantin Skokov[1], and Oliver Gutfleisch[1] —

[1]TU Darmstadt, Institut für Materialwissenschaft, 64287 Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Ni-Mn-In-(Co) Heusler compounds exhibit very promising magnetocaloric properties upon the first-order transition between low temperature, low magnetization martensite to high temperature, high magnetization austenite. Thereby, the phase transformation is characterized by a shear lattice distortion, which takes place via nucleation and growth. We studied the transition process of Ni-Mn-In by simultaneous adiabatic temperature change and strain measurements in pulsed magnetic fields. By different field-sweep rates, kinetical effects of the martensitic transformation were investigated. Moreover, the influence of the initial sample temperature on critical transformation field, field hysteresis and reversibility was analyzed and correlated with isofield measurements of magnetization, strain and resistivity.

The work was supported by the European Research Council (ERC) under the European Union*s Horizon 2020 research and innovation programme (grant no. 743116*project Cool Innov). We thank the HLD at HZDR, member of the European Magnetic Field Laboratory (EMFL) and the Helmholtz Association for funding via the Helmholtz-RSF Joint Research Group (Project No. HRSF-0045)

MA 61.5 Fri 10:30 HSZ 101

Thermomagnetic properties of Co or Cu doped Ni-Mn-Ga films for mico energy harvesting — •Lukas Fink[1,2], Anett Diestel[1], Kornelius Nielsch[1,2], and Sebastian Fähler[1] — [1]Leibniz IFW Dresden, Institute for Metallic Materials, D-01171 Dresden, Germany — [2]TU Dresden, Institute of Materials Science, D-01062 Dresden, Germany

Recovery of waste heat is decisive for a more efficient use of primary energy. Furthermore, at the micro scale it enables the Internet of Things without the need for wiring. However, except for thermoelectrics, there is hardly any technology available to harvest low temperature waste heat. As an alternative approach recently first thermomagnetic microsystems were developed, which use magnetocaloric materials as active material. The high surface-to-volume ratio of thin films enables a fast heat transfer, resulting in high cycling frequencies and power densities compared to bulk devices.

For this application we prepare Ni-Mn-based Heusler films by sputter deposition. We focus on Ni-Mn-Ga-X films (X= Cu, Co) and examine the role of the doping elements and chemical order on 1) the transition temperature, 2) hysteresis losses, and 3) difference of magnetization at the martensitic transition, which is the decisive property for thermomagnetic harvesting of low temperature waste heat. We discuss the suitability of these alloys for thermomagnetic harvesting of low temperature waste heat in comparison to magnetocaloric refrigeration.

This work is funded by the DFG (FA453/14).

MA 61.6 Fri 10:45 HSZ 101

Orbital Nernst Effect of Magnons — •Li-chuan Zhang[1,2], Fabian R. Lux[1,2], Jan-Philipp Hanke[1], Patrick M. Buhl[3], Sergii Grytsiuk[1], Stefan Blügel[1], and Yuriy Mokrousov[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

In the past, magnons have proven to mediate thermal transport of spin in various systems (see references in e.g. [1]). We will reveal that the fundamental coupling of the scalar spin chirality, inherent to magnons, to the electronic degrees of freedom in the system can result in the generation of sizeable orbital magnetization and thermal transport of orbital angular momentum. We will demonstrate the emergence of the latter phenomenon of the orbital Nernst effect by referring to the spin-wave Hamiltonian of Kagome ferromagnets and predict that in a wide range of systems the transverse current of orbital angular momentum carried by magnons in response to an applied temperature gradient can overshadow the accompanying spin current [2]. We suggest that the discovered effect fundamentally correlates with the topological Hall effect of fluctuating magnets, and suggest that it can be utilized in magnonic devices for generating magnonic orbital torques. We acknowledge funding from DFG through SPP 2137 "Skyrmionics", DARPA TEE Program and CSC (No. [2016]3100). [1] L.Zhang *et al.*, arXiv:1901.06192 (2019); [2] L.Zhang *et al.*, arXiv:1910.03317 (2019)

MA 61.7 Fri 11:00 HSZ 101

Magnonic Analogue of Edelstein Effect in Antiferromagnetic Insulators — Bo Li[1], •Alexander Mook[2], Aldo Raeliarijaona[1], and Alexey Kovalev[1] — [1]Department of Physics and Astronomy and Nebraska Center for Materials and Nanoscience, University of Nebraska, Lincoln, Nebraska 68588, USA — [2]Department of Physics, University of Basel, CH-4056 Basel

The electronic Edelstein or inverse spin-galvanic effect comprises a nonequilibrium spin density as response to a charge current [1]. Herein [2], we investigate the nonequilibrium spin polarization due to a temperature gradient in antiferromagnetic insulators, which is the magnonic analogue of the Edelstein effect.

We derive a linear response theory of a temperature-gradient-induced spin polarization in collinear and noncollinear antiferromagnets and present selected examples in one, two, and three dimensions. Assuming a realistic temperature gradient of 10 K/mm, we find two-dimensional spin densities of up to $\sim 10^6\,\hbar/\mathrm{cm}^2$ [e.g., in the noncollinear kagome antiferromagnet $KFe_3(OH)_6(SO_4)_2$] and three-dimensional bulk spin densities of up to $\sim 10^{14}\,\hbar/\mathrm{cm}^3$, encouraging an experimental detection.

[1] A. Aronov and Y. B. Lyanda-Geller, JETP Lett. **50**, 431 (1989); V. Edelstein, Solid State Commun. **73**, 233 (1990); [2] B. Li, A. Mook, A. Raeliarijaona, A. Kovalev, preprint arXiv:1910.00143

MA 61.8 Fri 11:15 HSZ 101

Non-hysteretic first-order ferromagnetic transitions by itinerant electron feedback and Fermi surface topology change — •Eduardo Mendive Tapia[1,2], Durga Paudyal[3], Leon Petit[4], and Julie Staunton[2] — [1]Max-Planck Institut für Eisenforschung, Düsseldorf, Germany — [2]Dept of Physics, University of Warwick, Coventry, UK — [3]The Ames Laboratory, U.S. Dept of Energy, Iowa State University, USA — [4]Daresbury Laboratory, Warrington, UK

Refrigeration and air conditioning are crucial in modern life and in adapting to climate change. Discontinuous magnetic phase transitions have great promise for new, energy efficient and environmentally friendly solid-state cooling technology. Huge exploitable entropy and temperature changes typically result from the coupling between a material's spin polarized interacting electrons and the crystal structure. Such magnetostructurally driven cooling, however, is nearly always degraded by hysteresis. We present an *ab-initio* theory which can find mechanisms for first-order magnetic phase transitions that are purely electronic in origin [1], thus avoiding the need for magnetostructural effects. We show that this electronic mechanism arises from an itinerant electron feedback to magnetic order. In particular, it is demonstrated that a topological change of the Fermi surface explains the hysteresis-free giant cooling properties recently measured in Eu_2In [2].—This work is funded by the EPSRC (UK) and the U.S. Dept of Energy, and forms part of the PRETAMAG project (University of Warwick).

[1] E Mendive-Tapia and J Staunton, Phys. Rev. B **99**, 144424 (2019)
[2] F Guillou *et al.*, Nat. Comm. **9**, 2925 (2018)

MA 61.9 Fri 11:30 HSZ 101

Utilizing the Thermomagnetic Response of the Magnetocaloric alloy Energy Harvesting Application — •Deepak Kamble[1,2] and Raju V. Ramanujan[1] — [1]School of Materials Science and Engineering, Nanyang Technological University, Singapore 639798 — [2]Present address: Leibniz IFW Dresden, Institute for Metallic Materials, Helmholtzstraße 20, 01069 Dresden, Germany

Thermal management is important to convert waste heat to useful electricity. Here we present an approach based on magnetocaloric materials, which allows us to harvest electricity from waste heat. As a first step we synthesized and characterized (MnNiSi)1-x(Fe2Ge)x alloys exhibiting 1st order magnetostructural transition. The alloys have a highly tunable transition range near room temperature with promising magnetocaloric parameters [K. Deepak et al., J. Alloys Compd. 743 (2018) 494-505]. As a second step the thermomagnetic response of the alloy with suitable transition temperature was utilized as working material to develop a novel hybrid thermomagnetic oscillator for electricity harvesting using waste heat from a heat load. The thermomagnetic alloy (TMA) was suspended in a quartz tube between heat load at the top and heat sink at the bottom resulting in oscillation of TMA due to the thermomagnetic response. The continuous oscillation gives rise to a magnetic flux change in the coil to generate electricity as well as transfers the heat from the heat load to the heat sink [K. Deepak et al., Applied Energy 233-234 (2019) 312-320].

MA 61.10 Fri 11:45 HSZ 101

Optimizing a thermomagnetic generator with flux reversal by finite element calculations — •Dietmar Berger[1], Daniel

Dzekan[1], Deepak Kamble[1,2], Kornelius Nielsch[1], and Sebastian Fähler[1] — [1]IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany — [2]School of Materials, Science and Engineering, Nanyang Technological University, Singapore 639798

Climate protection and the efficient use of primary energy are increasingly gaining the focus of public interest. Against this background, the generation of electrical energy from environmentally friendly and regenerative energy sources is increasingly important. In particular the huge amount of low temperature waste heat below 100 °C is almost not reusable.

The discovery of the giant magnetocaloric effect by Pecharsky and Gschneidner in 1997 [1] led to the development of new materials exhibiting a sharp change in magnetization in vicinity of room temperature. These materials also enabled the inverse energy conversion process: thermomagnetic harvesting of low temperature waste heat.

In this presentation we use our recent thermomagnetic generator with flux reversal as starting point [2]. The focus of our current work is to increase both, the conversion efficiency and the cycle frequency. By using FEM simulations we analyze the drawbacks of the present demonstrator and sketch improvements for the next generation of thermomagnetic generators.

[1] V. K. Pecharsky and K. A. Gschneidner, Jr., Phys. Rev. Lett. 78, 4494 (1997) [2] A. Waske et al., Nature Energy 4, 68-74 (2019)

MA 61.11 Fri 12:00 HSZ 101

Evaluation of magnetocaloric materials for thermomagnetic energy harvesting — •Daniel Dzekan[1,2], Anja Waske[3], Kornelius Nielsch[1,2], and Sebastian Fähler[2] — [1]Technical University Dresden, Institute for Material Science — [2]Leibniz IFW Dresden, Institute for Metallic Materials — [3]Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany

Nowadays recovering waste heat becomes decisive to use the limited primary energy most effective. A promising way to do so is the usage of thermomagnetic systems. Within these, heat is first converted into magnetic energy and then into electricity. Early device concepts had been suggested by Edison and Tesla but only few of them were realized. This changed due to the emerging field of magnetocaloric cooling and the development of new materials. These exhibit a steep change of magnetisation in a narrow temperature range, which paved the way for several thermomagnetic demonstrators and prototypes. Recently we presented a thermomagnetic generator with a novel design of the magnetic circuit, which increased the power output, frequency and efficiency significantly [1]. Here we identify and analyse the material requirements for a more energy and economic efficient conversion. We describe the influence of magnetisation change and heat capacity on thermodynamic efficiency, as well as the consequences of thermal conductivity on power density. [1] Waske et al., Nature Energy 4, 68-74 (2019)

MA 61.12 Fri 12:15 HSZ 101

The impact of hydrogenation and chemical substitution on the itinerant electron metamagnetism in La-Fe-Si-based magnetocaloric materials — •Markus Ernst Gruner — Faculty of Physics and Center for Nanointegration, CENIDE, University of Duisburg-Essen, Germany

State-of-the-art magnetocaloric materials like La-Fe-Si or FeRh are characterized by an intricate coupling between the electronic structure, magnetism and lattice, which is responsible for the large entropy change occuring at a first-order metamagnetic transition. Recent investigations prove that first-principles calculations in the framework of density functional theory (DFT) are in excellent agreement with element-resolved experimental techniques such as nuclear resonant inelastic X-ray-scattering, X-ray absorption or Mössbauer spectroscopy and can thus help to disentangle the interplay of the different degrees of freedom [1]. This contribution reports on recent DFT-based advances regarding the impact of interstitial doping with hydrogen and chemical substitution with transition metals and main group elements on magneto-elastic coupling and the functional properties of La-Fe-Si-based materials.

Funding from DFG in the framework of SPP 1599 and TRR 270 is gratefully acknowleged.

[1] F. Scheibel *et al.*, Energy Technology **6**, 1397 (2018).

MA 61.13 Fri 12:30 HSZ 101

Tailoring the Phase Transition of FeRh by Nickel Doping — •Tobias Lojewski[1], Benedikt Eggert[1], Alisa Chirkova[2], Konstantin Skokov[2], Iliya Radulov[2], Olga Shuleshova[3], Markus E. Gruner[1], Katharina Ollefs[1], Ivan Kaban[3], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Functional Materials, TU Darmstadt — [3]IFW Dresden

FeRh in the B2-crystal structure shows a substantial magnetocaloric effect during the metamagnetic phase transition from the AFM to the FM phase, at a transition temperature around 400 K. This phase transition can be tuned using Ni as dopant, shifting the phase transition to lower temperatures [1] and making the system more relevant for room temperature applications. As such, the effects of nickel doping were studied in a $Fe_{49}Rh_{50}Ni_1$ sample using Conversion Electron Mössbauer Spectroscopy (CEMS) to obtain a microscopic picture of the ^{57}Fe-nuclei surroundings during the phase transition. Here a reduced transition temperature of about 327 K can be observed. From the CEMS measurements, a possible electron transfer from nickel to iron is indicated by a variation in the isomer shift. Additionally, a similar hyperfine field can be observed in both FeRh and FeRhNi for the identical phases, suggesting no change of the irons magnetic moments. The microscopic magnetic structure is then compared to macroscopic magnetic properties obtained from magnetometry data. Financial support by DFG(WE2623/14-1) and CRC/TRR 270 is acknowledged.

[1] Baranov NV, Barabanova EA. J All Comp 1995;219:139

MA 61.14 Fri 12:45 HSZ 101

Experimental determination of the thermal conductivity of oxide barriers in magnetic tunnel junctions — Hyejin Jang[1], Luca Marnitz[2], Torsten Huebner[2], Johannes Kimling[1], Ulrike Martens[3], Jakob Walowski[3], Markus Münzenberg[3], Andy Thomas[4], Günter Reiss[2], David Cahill[1] und •Timo Kuschel[2] — [1]University of Illinois, Urbana, USA — [2]Bielefeld University, Germany — [3]Greifswald University, Germany — [4]IFW, Dresden, Germany

The tunnel magneto-Seebeck (TMS) effect in magnetic tunnel junctions (MTJs) has large potential for future nanoelectronic devices [1]. However, quantitative determination of the TMS coefficients requires knowledge of the temperature drop across the tunnel barrier and, thus, of the thermal conductivity of the oxide barrier material. Here, we present two new approaches to obtain the barrier's thermal conductivity, which is usually difficult to access experimentally. For the first approach, we utilize laser-induced TMS in combination with finite-element modeling extracting values of the thermal conductivity of 0.7 W/(K·m) for $MgAl_2O_4$ and 5.8 W/(K·m) for MgO [2]. The second method uses ultrafast thermoreflectance and magnetooptic Kerr effect thermometry and provides values of the thermal conductivity of 0.4-0.6 W/(K·m) for both oxide barrier materials [3]. These results are in nice agreement with theoretical predictions for ultra-thin oxide barriers [4].

[1] Kuschel et al., J. Phys. D: Appl. Phys. 52, 133001 (2019)
[2] Huebner et al., J. Phys. D: Appl. Phys. 51, 224006 (2018)
[3] Jang, Marnitz, Huebner, Kimling, Kuschel, Cahill, under review
[4] Zhang et al., Phys. Rev. Lett. 115, 037203 (2015)

MA 61.15 Fri 13:00 HSZ 101

Magnetic phase diagram of the magnetocaloric compound Mn3Fe2Si3 — •Mohammed Ait Haddouch[1], Jörg Voigt[1], Karen Friese[1], Andreas Eich[1], Jörg Persson[1], Armand Budzianowski[2], Nicolò Violini[1], Fabiano Yokaichiya[3], Devashibhai Adroja[4], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science (JCNS-2) and PGI-4, Forschungszentrum Jülich , Germany — [2]National Centre for Nuclear Research,Otwock ,Poland — [3]Helmholtz-Zentrum Berlin für Materialien und Energie,Germany — [4]ISIS Facility, Rutherford Appleton Laboratory,U.K

We have studied the magnetic phases of single-crystalline $Mn_3Fe_2Si_3$ by neutron diffraction and magnetization measurements. Within the series $Mn_{5-x}Fe_xSi_3$, an inverse magneto-caloric effect (MCE) has been observed for x=0, while for x=4 a moderately high direct MCE occurs [1]. Similarly to the parent compound Mn_5Si_3, $Mn_3Fe_2Si_3$ exhibits two antiferromagnetic phase transitions to an AF1 and AF2 phase, respectively. The transition from AF1 → AF2 gives rise to an inverse MCE, i.e. the magnetic entropy is increased by the application of a magnetic field, albeit with complex field and temperature dependences. We discuss these changes in light of the preferential replacement of Mn by Fe on one of the two distinct lattice sites of the crystal structure (space group $P6_3/mcm$ at RT). This leads to an increase in the transition temperatures and critical fields when compared to Mn_5Si_3. In addition, we find hints for ferromagnetic short-range correlations, which persist at temperatures twice as high as the Neel temperature. [1] Songlin et al, J. Alloys Compd, 334, 249−252 (2002)

MA 62: Disodered Magnetic Materials

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

MA 62.1 Fri 9:30 HSZ 401

An ab initio study of magnetism in disordered Fe-Al alloys with thermal antiphase boundaries — •Martin Friák[1], Miroslav Golian[1], David Holec[2], Nikola Koutná[3], and Mojmír Šob[1] — [1]Institute of Physics of Materials, Czech Academy of Sciences, Brno, Czech Republic — [2]Department of Materials Science, Montanuniversität Leoben, Leoben, Austria — [3]Institute of Materials Science and Technology, TU Wien, Vienna, Austria

We have performed a quantum-mechanical study of a disordered B2 phase of $Fe_{70}Al_{30}$ alloy with and without antiphase boundaries (APBs) with the {001} crystallographic orientation of APB interfaces. We used a supercell approach with the atoms distributed according to the special quasi-random structure (SQS) concept. Our study was motivated by experimental findings by Murakami *et al.* (Nature Comm. 5 (2014) 4123) who reported significantly higher magnetic flux density from A2-phase interlayers at the thermally-induced APBs in $Fe_{70}Al_{30}$ and suggested that the ferromagnetism is stabilized by the disorder in the A2 phase. Our computational study confirms this suggestion (Friák *et al.* (2019), submitted to Nanomaterials) and explains details of the underlying mechanism. The Fe atoms in the A2 phase have the average magnetic moment by 17.5 % higher than in the B2 phase. We link the changes in the magnetism to the fact that the Al atoms in the first nearest neighbor shell of Fe atoms nonlinearly reduce their magnetic moments (M. Friák and J. Neugebauer, Intermetallics 18 (2010) 1316). Lastly, our atomistic simulations of sharp APBs confirmed a temperature-dependent formation of the A2-phase interlayers.

MA 62.2 Fri 9:45 HSZ 401

Variation of open volume defects during magnetic phase transitions — •Maciej Oskar Liedke[1], Maik Butterling[1], Jonathan Ehrler[1], Benedikt Eggert[2], William Griggs[3], Shadab Anwar[1], Rantej Bali[1], Thomas Thomson[3], Eric Hirschmann[1], Ahmed G. Attallah[1], Heiko Wende[2], and Andreas Wagner[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Duisburg-Essen, Duisburg, Germany — [3]The University of Manchester, Manchester, United Kingdom

Open volume defects in Fe60Al40 and Fe50Rh50 alloy thin films have been investigated with positron annihilation spectroscopy techniques. The distribution of open-volume defect types in Fe60Al40 thin films, i.e., mono-vacancies, triple defects as well as vacancy clusters has been estimated using positron annihilation lifetime spectroscopy. We show that the temperature driven re-ordering kinetics can be strongly modified by controlling the defect distribution through annealing and ion irradiation treatments. In particular, the splitting of vacancy clusters and triple defects into mono-vacancies by irradiation accelerates thermal diffusion, lowering the temperature necessary for re-ordering [J. Ehrler, et al., Acta Mater. 176 (2019) 167]. In case of B2 Fe50Rh50 thin films, ion irradiation induces a ferromagnetic behaviour in the initially antiferromagnetic thin films. The variation of open-volume defects during this transition has been tracked. We will demonstrate that irradiation induces open volume defects, whose concentration scales with ion fluence, providing insights on the types of defects associated with ferromagnetism in the Fe50Rh50 system.

MA 62.3 Fri 10:00 HSZ 401

Large Hall angle of the disordered B2 $Fe_{60}Al_{40}$ alloy — •Václav Drchal[1], Josef Kudrnovský[1], František Máca[1], Ilja Turek[2], and Sergii Khmelevskyi[3] — [1]Inst. of Physics, Czech Acad. Sci., Praha, Czech Republic — [2]Inst. of Physics of Materials, Czech Acad. Sci., Brno, Czech Republic — [3]Center for Computational Materials Science, Vienna University of Technology, Austria

The electronic and transport properties of the ordered B2 $Fe_{60}Al_{40}$ alloy which undergoes a continuous transition into disordered A2 $Fe_{60}Al_{40}$ phase are studied from first principles. Variation of the alloy disorder due to Fe antisites on Al sublattice is characterized by the partial long-range order. This is the simplest model of gradual disordering of the ordered phase due to the ion irradiation. The physical properties are strongly influenced by varying local environment of Fe atoms on both sublattices. This leads to the transition between a very low moment in the ordered phase to a high moment at large disorder. Similar behavior is found also for anomalous Hall conductivity and anomalous Hall angle. The disordered phase has a large Hall angle as contrasted with a negligible Hall angle for well ordered samples, which is in agreement with recent experiment.

MA 62.4 Fri 10:15 HSZ 401

Local structure after ion irradiation in FeRh thin films — •Johanna Lill[1], Benedikt Eggert[1], Katharina Ollefs[1], Sakura Pascarelli[2], Alexander Schmeink[3,4], Kay Potzger[3], Jürgen Lindner[3], Jürgen Fassbender[3,4], Thomas Thomson[5], Rantej Bali[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]ESRF, Grenoble, France — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]Dresden University of Technology, Germany — [5]The University of Manchester, United Kingdom

B2 FeRh shows antiferromagnetic ordering in the thermodynamic stable phase, while the disordered structure exhibits a ferromagnetic and paramagnetic ordering. The disordered structure can be induced by ion irradiation [1]. In this work we investigate FeRh thin films for different irradiation fluences of 110 keV Ne^+ by Fe K edge Extended X-ray absorption fine structure spectrosopy at low temperatures. For low irradiation fluences, we see an increase of the lattice parameter and an increase of static disorder by analysis of the mean square relative displacement. For higher fluences a change from the bcc to the fcc phase occurs. In addition, XRD measurements show similar behaviour to the EXAFS findings. From magnetometry, we determine an increase of the magnetisation and a shift of the phase transition to lower temperatures with rising irradiation fluence. Financial support by DFG (WE 2623/14-1) is acknowledged.

[1] A. Heidarian et al. J. Nucl Inst. Meth. B 358, 251 (2015)

MA 62.5 Fri 10:30 HSZ 401

Spin wave spectra of disordered materials — •Sebastian Paischer[1], Pawel Buczek[2], and Arthur Ernst[1] — [1]Johannes Kepler Universität Linz — [2]Hochschule für Angewandte Wissenschaften Hamburg

We use a new approach to calculate the Magnon dispersion of randomly disordered alloys based on the coherent potential approximation. The main features of our theory are the inclusion of both diagonal and off-diagonal disorder and the fact that we are not restricted to simple lattices and interactions. Additionally we are able to satisfy the Goldstone-theorem which is not always the case for many studies found in the literature. We augment the method to account for temperature dependence within the random phase approximation. In this talk I will present our results, e.g. the temperature- and concentration-dependence of disordered iron-cobalt alloys and the Heusler-alloy Ni_2MnSn of which we investigate the influence of antisite defects.

MA 62.6 Fri 10:45 HSZ 401

Impact of correlation effects on the magneto-optical Kerr effect in transition metals and their alloys — •Andreas Held[1], Ján Minár[2], and Hubert Ebert[1] — [1]Department Chemie, Ludwig-Maximilians-Universität München — [2]New Technologies-Research Center, University of West Bohemia, Pilsen

The magneto-optical Kerr effect (MOKE) is a well-established tool for investigating the properties of magnetic systems. Originating from the subtle interplay between magnetic order and spin-orbit coupling, a proper theoretical description of MOKE requires an appropriate framework. Such a scheme has been worked out by Huhne [1] on the basis of the fully relativistic spin-polarized Korringa-Kohn-Rostoker method [2]. To allow for the treatment of substitutionally disordered systems, the approach has been combined with the coherent potential approximation (CPA) alloy theory. The extended scheme gives access to the configurationally averaged optical conductivity tensor and this way to the corresponding complex Kerr angle. The additional combination with Dynamical Mean Field Theory (DMFT) [3] allows in particular to investigate the influence of correlation effects on the MOKE in disordered systems. Corresponding results for pure Ni, Fe and Co as well as disordered Fe_xCo_{1-x} and Co_xPt_{1-x} alloys are presented and compared with experimental data.

[1] Huhne, Ebert, *Phys. Rev. B* **60**, 12982 (1999); Huhne, Ebert, *Phys. Stat. Sol. B* **215**, 839 (1999)
[2] Ebert, Ködderitzsch, Minár, *Rep. Prog. Phys.* **74**, 096501 (2011)

[3] Minár et al., *Phys. Rev. B* **72**, 045125 (2005)

MA 62.7 Fri 11:00 HSZ 401

Local short-scale correlations and the origin of pseudo-diamagnetism — •Malvika Tripathi[1], T. Chatterji[2], H. E. Fischer[2], R. J. Choudhary[1], and D. M. Phase[1] — [1]UGC-DAE Consortium for Scientific Research,Indore-452001, India — [2]Institut Laue-Langevin, 38042 GRENOBLE Cedex, France

Here we describe why the antiferromagnetically ordered $GdCrO_3$ behave in a diamagnetic way under certain conditions, by monitoring the evolution of the microscopic global and local magnetic phases. High energy neutron diffraction reveals that magnetic ordering comprises three distinct magnetic phases at different temperatures: G_x^{Cr},A_y^{Cr},F_z^{Cr} below Néel temperature = 171 K; (F_x^{Cr}, C_y^{Cr}, G_z^{Cr})•(${F_x}^{Gd}$,${C_y}^{Gd}$) below 7 K and an intermediate phase for 7 K $\leq T \leq$ 20 K in the vicinity of spin-reorientation phase transition. Although, bulk magnetometry reveals a huge negative magnetization (NM) in the terms of both magnitude and temperature range; the long-range magnetic structure and derived ordered moments remain silent about any signature of NM. Real-space analysis of the total scattering suggests significant magnetic correlations extending up to $\sim$ 9 Å. Accounting for these short-range correlations with a spin model reveals spin frustration in the S= 3 ground state, comprising competing first, second and third next nearest exchange interactions with values J_1 = 2.3 K, J_2 = -1.66 K and J_3 = 2.19 K in presence of internal field, governs the observance of NM in $GdCrO_3$.

MA 62.8 Fri 11:15 HSZ 401

Uniform Heisenberg spin chain in sarrabusite $Pb_5Cu(SeO_3)_4Cl_4$ — •Ekaterina Kozlyakova, Artem Moskin, Alisher Murtazoev, Peter Berdonosov, and Alexander Vasiliev — Lomonosov MSU, Moscow, Russia

One-dimensional antiferromagnets have exotic disordered ground states. The uniform half-integer spin chain does not present a gap in the triplet excitation spectrum and it is disordered in an isotropic Heisenberg case. In any real material an ideal S = 1/2 chain cannot exist because an infinitesimal interchain coupling would give rise to long-range magnetic order at finite temperatures. [1, 2] In this work we present novel uniform spin chain compound $Pb_5Cu(SeO_3)_4Cl_4$ that demonstrates no long-range magnetic ordering up to 2 K. Its magnetic susceptibility agrees well with the Bonner-Fisher's model with J = 129K for Heisenberg AFM S = 1/2 spin chain [3]. Thus, $Pb_5Cu(SeO_3)_4Cl_4$ is one of the very few uniform spin chains where no long-range magnetic ordering or any singlet formation were observed above 2 K, while J is of the order of 100 K.

[1] E. Lieb, et al. Annals Phys. 16, 407-466 (1961).
[2] D.C. Johnston, et al. Phys. Rev. B 61, 9558-9606 (2000).
[3] J.C. Bonner & M.E. Fisher. Phys. Rev. A 135, 640-658 (1964).

MA 63: Spin: Transport, Orbitronics and Hall Effects III

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

MA 63.1 Fri 9:30 HSZ 403

Spin and anomalous Hall effect induced charge and spin currents in ferromagnetic/nonmagnetic heterostructures — •Albert Hönemann[1], Christian Herschbach[1], Dmitry V. Fedorov[2], Martin Gradhand[3], and Ingrid Mertig[1,4] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]University of Luxembourg, Luxembourg, Luxembourg — [3]University of Bristol, Bristol, United Kingdom — [4]Max Planck Institute of Microstructure Physics, Halle, Germany

Transport phenomena caused by spin-orbit coupling such as spin Hall effect (SHE) and anomalous Hall effect (AHE) are highly relevant topics of current research. In ferromagnetic/nonmagnetic heterostructures, the interplay of spin-orbit and exchange interaction causes new phenomena like spin-orbit torques [1].

We use an *ab initio* approach based on a relativistic Korringa-Kohn-Rostoker method to determine the electronic structure [2] and solve the linearized Boltzmann equation to describe the electronic transport [3]. We apply these methods to a Co/Cu superlattice with different substitutional impurities delta-distributed within the individual atomic layers [4]. We investigate the AHE-induced charge current as well as the SHE-induced spin current perpendicular and parallel to the interface and report on the spatial distribution of charge and spin current with respect to the interface.

[1] Gambardella *et al.*, Phil. Trans. R. Soc. A **369**, 3175 (2011); [2] Gradhand *et al.*, PRB **80**, 224413 (2009); [3] Gradhand *et al.*, PRL **104**, 186403 (2010); [4] Hönemann *et al.*, PRB **99**, 024420 (2019);

MA 63.2 Fri 9:45 HSZ 403

Spin-dependent transport in Uranium — •Ming-Hung Wu, Hugo Rossignol, and Martin Gradhand — H. H. Wills Physics Laboratory, University of Bristol, Bristol BS8 1TL, United Kingdom

Uranium, a naturally occurring heavy metal with 5f-electrons, has been investigated for decades due to its complex properties.1 Despite its narrow 5f-bands, the hybridization with 6d-bands provides itinerant electrons, distinct from other 5f actinides. In combination with its strong spin-orbit coupling, uranium is a promising material for spintronic applications e.g. magnetic multilayer systems.2-5 Furthermore uranium crystallizes in a large variety of structures such as α (orthorhombic), β (bct), γ (bcc) and hcp phase, it shows superconductivity and is close to a ferromagnetic transition. In order to shed light on the complex physics in such systems, we focus on the spin-dependent transport of uranium for a variety of phases. In our ab initio calculations we analyze the intrinsic spin Hall effect as well as the extrinsic mechanism incorporating various impurities for bulk γ, hcp and α uranium. We discuss the effects of crystal structures and magnetic moments of impurities on the spin-dependent transport.

Reference 1.S. Adak, H. Nakotte, P. de Chatel, B. Kiefer, Phys. B 406, 3342 (2011). 2. Kevin T. Moore and Gerrit van der Laan, Rev. Mod. Phys. 81, 235 (2009). 3. R. Springell, F. Wilhelm, A. Rogalev, W. G. Stirling, R. C. C. Ward, M. R. Wells, S. Langridge, S. W. Zochowski, and G. H. Lander, Phys. Rev. B 77, 064423 (2008). 4. A. Laref, E. Şaşioglu, L. M. Sandratskii, J. Phys.: Condens. Matter 18, 4177 (2006).

MA 63.3 Fri 10:00 HSZ 403

The spin Hall effect in β-W and interstitial impurities — •O. L. W. McHugh[1], M. Gradhand[1], W. F. Goh[2], and D. A. Stewart[3] — [1]University of Bristol, UK — [2]University of California at Davis, Davis, CA, USA — [3]Western Digital Corporation, San Jose, CA, USA

One of the best metals to convert charge into spin current via the spin Hall effect (SHE) [1] is β-W. Its structural stabilization requires doping with O and N [2] atoms. In addition, increasing the impurity concentration enhances its SHA [3]. The exact mechanism of this enhancement is unknown. We present *ab-initio* calculations to investigate these impurities for both α-W (bcc) and β-W on both the intrinsic and the extrinsic mechanism. We compare the PAOFlow[4] code using the Kubo formula with the semi classical description via the Berry curvature as implemented in the KKR [5]. For further investigations in impurities, as well as structural relaxation, we rely on the PAOFlow for the intrinsic and the KKR-Boltzmann method for the extrinsic contribution. We found good agreement to experiment, highlighting that for β-W the reduction of the charge conductivity is driving the effective charge to spin conversion. Beyond stabilization, the effect of impurities is small and a quantitative analysis will be presented.

[1] C.-F. Pai *et al.*, Appl. Phys. Letters, **101**(12) (2012)
[2] J. Liu, Doctoral Theses, Columbia University, NY, USA (2016)
[3] K.-U. Demasius *et al.*, Nat. Comm., **7**, 10664 (2016)
[4] M. Nardelli *et al.*, Comp. Mat. Science **143**, 462-472 (2018)
[5] M. Gradhand *et al.*, Phys. Rev. B, **84**, 075113 (2011)

MA 63.4 Fri 10:15 HSZ 403

Spin-orbital coupled dynamics in (Fe,Ni)/W(110) from first principles — •Dongwook Go[1,2,3], Frank Freimuth[1], Jan-Philipp Hanke[1], Stefan Blügel[1], Hyun-Woo Lee[2], and Yuriy Mokrousov[1,4] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52428 Jülich, Germany — [2]Department of Physics, Pohang University of Science and Technology, Pohang 37673, Korea — [3]Basic Science Research Institute, Pohang University of Science and Technology, Pohang 37673, Korea — [4]Institute of Physics, Johannes Gutenberg University

Mainz, 55099 Mainz, Germany

A common wisdom in spintronics is that angular momentum is carried by the spin of electrons. In current-induced spin dynamics, however, we recently showed that the orbital degree of freedom plays a fundamental role, where spin dynamics follows the orbital dynamics by the spin-orbit coupling [1]. Thus, spin and orbital degrees of freedom exhibit entangled dynamics in general. In this talk, we present our recently developed formalism that consistently describes angular momentum transfer dynamics between spin and orbital degrees of freedom of electrons, and their interaction with lattice and local magnetic moment. We apply this formalism to (Fe,Ni)/W(110), and show that the orbital current injection critically affects the magnetization dynamics when the ferromagnet is Ni, which is consistent with a recently proposed orbital torque mechanism [2]. We acknowledge fundings from DFG (SPP 2137) and SSTF (BA-1501-07). [1] Go *et al.* Phys. Rev. Lett. **121**, 086602 (2019); [2] Go *et al.*, arXiv:1903.01085 (2019).

MA 63.5 Fri 10:30 HSZ 403

Fast screening of THz current pulses in heavy metal/ferromagnet bilayers — •Wolfgang Hoppe[1], Rouven Dreyer[1], Liane Brandt[1], Tobias Kampfrath[2], Mazhar Nawaz Ali[3], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Physics, Halle, Germany — [2]Freie Universität Berlin, Physics, Berlin, Germany — [3]Max-Planck Institute of Microstructure Physics, Halle, Germany

We use femtosecond optical pump pulses to generate ultrashort current pulses in heavy metal/ferromagnet bilayers. The optical excitation from an ultrafast amplified laser system injects ultrashort spin current pulses from the ferromagnet into the heavy metal layer via the spin-dependent Seebeck effect [1]. Subsequently, this spin current pulse is converted into a charge current pulse inside the heavy metal layer via the inverse spin-Hall effect (ISHE) [2]. To investigate these ultrafast current pulses there are two different approaches available. Quantitatively, the exact waveform can be measured using electrooptic sampling. Qualitatively, a probing tip connected to a 50 GHz sampling oscilloscope yields a quick method to characterize the ISHE in plain films and microstructured devices. This fast approach can be utilized to investigate the signal dependence on varying layer thicknesses, different layer materials and wedged interlayers between the heavy metal and ferromagnetic layer.

[1] A. Melnikov et. al.: doi: 10.1103/PhysRevLett.119.017202
[2] T. Seifert et. al.: doi:10.1038/nphoton.2016.91

MA 63.6 Fri 10:45 HSZ 403

Engineering the emission of spintronic terahertz emitters based on defect densities — •Laura Scheuer[1], Dennis Nenno[1], Garik Torosyan[2], Alexander Brodyanski[3], Rolf H. Binder[4], Hans C. Schneider[1], Rene Beigang[1], and Evangelos Th. Papaioannou[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Photonic Center Kaiserslautern, Kaiserslautern, Germany — [3]Institut für Oberflächen- und Schichtanalytik (IFOS) and Landesforschungszentrum OPTIMAS, Kaiserslautern, Germany — [4]College of Optical Sciences, University of Arizona, Tucson, USA

The field of THz spintronics aims to control ultrafast spin currents that could enable novel applications and devices operating in the THz range. While the generation of pulsed broadband THz radiation utilizing the inverse spin Hall effect in ferromagnetic/nonmagnetic (FM/NM) metallic heterostructures was investigated considering the influence of the layer thickness, substrate, geometry and excitation energy, the influence of the crystal structure was not yet studied. Here, we experimentally show the role of the defect density of the crystal structure. Modifying the defect density results in a change of the elastic electron-defect scattering lifetime in Fe and Pt and of the interface transmission for spin-polarized non-equilibrium electrons. Supporting the experimental findings, a theoretical model is employed, accounting for the differences in the elastic electron scattering lifetime and for the transmission of spin-polarized hot carriers at the FM/NM interface.

MA 63.7 Fri 11:00 HSZ 403

THz emission from XUV pumped spintronic tri-layer emitter: A prospective timing tool for FELs — •Naman Agarwal[1], Igor Ilyakov[2], Robert Carley[1], Jan-Christoph Deinert[2], Alexander Yaroslavtsev[1], Jia Liu[1], Loic le Guyader[1], Gabor Kurdi[3], Laura Foglia[3], Riccardo Mincigrucci[3], Emiliano Principi[3], Tobias Kampfrath[4,5], Sergey Kovalev[2], Michael Gensch[6,7], and Andreas Scherz[1] — [1]European XFEL GmbH, Schenefeld, Germany — [2]TELBE, HZDR, Dresden, Germany — [3]EIS-TIMEX, FERMI, Trieste, Italy — [4]Freie Universität Berlin, Germany — [5]Fritz-Haber-Institut, Berlin, Germany — [6]Technischen Universität Berlin, Germany — [7]DLR, Berlin, Germany

We demonstrate the strong broadband THz emission from spintronic trilayer (W/CoFeB/Pt) excited by XUV wavelengths. We discuss the possible mechanisms of generation of THz emission.

Further, in our timing diagnostics scheme, we demonstrate few-femtosecond arrival-time measurements based on single-shot electro-optic sampling(EOS) of broadband THz emission from an XUV-pumped spintronic THz emitter. Experiments were performed at the EIS-TIMEX beamline of FERMI, Italy. Using a spectral-encoding scheme for EOS, we were able to measure the arrival time with 20fs resolution, which compares well with other techniques.This technique requires very small fluence (10 uJ/cm^2), compared to other techniques(transient reflectivity) requiring 10 mJ/cm^2.We discuss possible improvements of this scheme, and how it can be combined with other scientific objectives.

15 min. break.

MA 63.8 Fri 11:30 HSZ 403

Spin dynamics driven by optical spin-orbit torque — •Ritwik Mondal, Andreas Donges, and Ulrich Nowak — Department of Physics, Universität Konstanz, Konstanz 78464, Germany

Interest in controlling spins by means of ultra-short light pulses has grown immensely due to its potential technological applications. To this end, several light-spin interaction effects can contribute to the spin dynamics, e.g., the nonrelativistic Zeeman effect. However, the relativistic light-spin coupling effects cannot be neglected if the laser power is higher. In this case, a spin precession occurs due to an additional optical spin-orbit torque (OSOT) [1]. It is believed that the OSOT originates from the relativistic spin-orbit coupling of excited non-equilibrium photo carriers that is independent of the helicity of the laser pulse [1]. Here, we examine the existence of an OSOT, a relativistic spin torque originating from the spin-orbit coupling of the applied field with the magnetic spins [2]. Our analytical calculations show that the OSOT depends on the helicity of the light and proportional to the intensity, while inversely proportional to the frequency. We compare the effects of the nonrelativistic Zeeman torque and the relativistic OSOT for magnetic systems excited by a circularly polarised laser pulse. Our results show that the optical spin-orbit torque could exert torques on the spins comparable to the Zeeman torque.

[1] N. Tesarova et. al. Nature Photonics **7**, 492 (2013)
[2] R. Mondal et. al. Phys. Rev. B **92**, 100402(R) (2015)

MA 63.9 Fri 11:45 HSZ 403

Effective damping of terahertz spin-wave modes in iron — •Liane Brandt[1], Niklas Liebing[1], Ilya Razdolski[2], Roman Verba[3], Vasyl Tyberkevych[4], Andrei Slavin[4], Georg Woltersdorf[1], and Alexey Melnikov[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics, Halle (Saale), Germany — [2]Fritz Haber Institute of the Max Planck Society, Department of Physical Chemistry, Berlin, Germany — [3]Institute of Magnetism, Kyiv, Ukraine — [4]Oakland University, Department of Physics, Rochester, USA

Recently, we have demonstrated the excitation of perpendicular standing spin waves (PSSW) in Fe/Au/Fe tri-layers studied by the time-resolved magneto-optical Kerr effect in a back pump-front probe scheme [1]. This high-frequency spin dynamic is driven by interface-confined spin transfer torque exerted by 250 fs-short spin current pulses generated in the optically excited emitter Fe layer [2]. The frequency of the PSSWs is tuned up to 2.5 THz by continuously reducing the thickness of collector Fe layer from 17 to 1 nm.

By analyzing the effective damping of the PSSW modes we observe an increase by two orders of magnitude in effective damping with increasing wave number. While the Gilbert damping is independent on the wave number, we can describe the increase in effective damping by the k-dependent spin diffusion term. Additional effects due to interfaces, defects in the volume and spin pumping appear to be small.

[1] I. Razdolski et al., Nat. Comm. 8, 15007 (2017)
[2] A. Alekhin et al., PRL 119, 017202 (2017)

MA 63.10 Fri 12:00 HSZ 403

Monte Carlo simulation of spin dynamics and spin transport in Iron (Fe) after femtosecond laser pulse irradiation —

•Johan Briones, Sebastian Weber, Sanjay Ashok, and Baerbel Rethfeld — Department of Physics and Optimas Research Center, University of Kaiserslautern, Germany

The potential use of electronic spin, rather than charge, as carrier of information has brought into consideration the importance of understanding the complex phenomena of spin transport arising after a magnetic film is excited by a femtosecond laser pulse. After laser exciting the metalic ferromagnet, modeled by a spin-dependent density of states, we trace individual electrons undergoing multiple individual scatterings using a kinetic Monte Carlo model. We analyze the spin dynamics by considering the generation of secondary electrons (electronic cascade) and the exchange scattering as a spin-flip mechanism. The simulation has been performed for Fe and we discuss the implications of our results for the spin transport.

MA 63.11 Fri 12:15 HSZ 403

Spin-Hall Nano-oscillators, optimized shape and fabrication strategies — •Stephanie Lake[1], Philipp Dürrenfeld[1], Frank Heyroth[2], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

Spin Hall nano-oscillators (SHNOs), typically a bilayer device comprised of Pt and a thin film of ferromagnetic material, exhibit auto-oscillations when spin transfer torque cancels out the damping torque applied on magnetization precession. Several publications focused on Py-based SHNOs with nanoconstrictions (NCs) show that high frequency (HF) electrical signals can be generated by taking advantage of the anisotropic magnetoresistance (AMR) effect in Py[1]. However, practical use of these HF signals is challenging due to their low power[1]. To increase power, one can improve auto-oscillations in SHNOs by manipulating its geometry and material parameters.

This work is a systematic investigation of Py-based SHNOs fabricated using different electron beam lithography (EBL) strategies to optimize shape and size of the constriction. We show simulations of the static field within NCs for geometries we want to pattern with EBL and subsequent fabrication attempts. Furthermore, we obtain the AMR ratio and Gilbert damping constant of our devices. Understanding how EBL affects SHNO characteristics will allow for future optimization.

[1]Awad, A. A. *et al.*, *Nat. Phys.* **13**, 292299 (2016).

MA 63.12 Fri 12:30 HSZ 403

Controlled nonlinear magnetic damping in spin-Hall nanodevices — •Boris Divinskiy[1], Sergei Urazhdin[2], Sergej O. Demokritov[1], and Vladislav E. Demidov[1] — [1]University of Münster, Münster, Germany — [2]Emory University, Atlanta, USA

Large-amplitude magnetization dynamics is substantially more complex compared to the low-amplitude linear regime, due to the inevitable emergence of nonlinearities. One of the fundamental nonlinear phenomena is the nonlinear damping enhancement, which imposes strict limitations on the operation and efficiency of magnetic nanodevices. In particular, nonlinear damping prevents excitation of coherent magnetization auto-oscillations driven by the injection of spin current into spatially extended magnetic regions. Here, we propose and experimentally demonstrate that nonlinear damping can be controlled by the ellipticity of magnetization precession. By balancing different contributions to anisotropy, we minimize the ellipticity and achieve coherent magnetization oscillations driven by spatially extended spin current injection into a microscopic magnetic disk. Our results provide a route for the implementation of efficient active spintronic and magnonic devices driven by spin current.

References:
[1] B. Divinskiy et al., Nature Comm. 10, 5211 (2019)

MA 63.13 Fri 12:45 HSZ 403

Spin pumping at the ferromagnetic/paramagnetic phase transition of Fe monolayers — •Evangelos Th. Papaioannou, Camillo Ballani, Christoph Hauser, and Georg Schmidt — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06120 Halle, Germany

Spin pumping is a powerful method to generate pure spin currents which are a key ingredient in spintronic devices. The microscopic nature of the spin current injection close to the magnetic phase transition is of great interest for future applications of magnetic nano-devices. The effect of spin pumping close to the magnetic phase transition has been only studied so far for paramagnetic insulating- and antiferromagnetic/Pt bilayers. On the contrary here, we show the effect of spin pumping and of inverse spin Hall effect (ISHE) undergoing a ferromagnetic to paramagnetic phase transition. We use ultra-thin Fe layers in Pd /Fe(1.2-1.7 monolayers)/Pd heterostructures with controllable Curie temperature. Temperature-dependent inverse spin Hall effect voltage measurements show that the ISHE signal remains persistent over a relatively wide temperature range above the Curie temperature. We correlate our spin pumping results to the spin correlation length and to the critical exponent of the transition. We discuss how spin pumping due to local magnetic order above the Curie temperature gives new insights into the pumping mechanism and how it can be turned into a simple microwave spin battery.

MA 64: Surface Magnetism II (joint session O/MA)

Time: Friday 10:30–13:45 Location: GER 38

MA 64.1 Fri 10:30 GER 38

Observation of tunable single-atom Yu-Shiba-Rusinov states — •Artem B. Odobesko[1], Domenico DiSante[2], Alexander Kowalski[2], Felix Friedrich[1], Ronny Thomale[2], Giorgio Sangiovanni[2], and Matthias Bode[1] — [1]Physikalisches Institut, Universität Würzburg, Am Hubland, Würzburg, Germany — [2]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, Würzburg, Germany

Through scanning tunneling spectroscopy, we analyze the interdependence of Kondo screening and superconductivity. Our data obtained on single Fe adatoms on Nb(110) show that the coupling and the resulting Yu-Shiba-Rusinov (YSR) bound states are strongly adsorption site-dependent and exhibit a quantum phase transition, where two YSR resonances cross at zero bias. By sweeping the external magnetic field to turn off and on superconductivity in the Nb substrate, we were able to study the interaction of individual magnetic adatoms with the normal-metallic or superconducting substrate in two consecutive experiments. The data show that the in-gap position of YSR states scales with the Kondo temperature and exhibits a cross-over at 0.7Δ, in good agreement with theoretically predicted value. The observed experimental signatures are rationalized by combined density functional theory and continuous-time quantum Monte-Carlo calculations. This treatment shows that the size of the magnetic moment and the hybridization of the impurity orbitals with the substrate are key parameters for understanding the interaction between magnetic adatoms and superconductors.

MA 64.2 Fri 10:45 GER 38

YSR states in manually assembled clusters of molecules on a superconducting surface — •Jan Homberg, Manuel Gruber, Alexander Weismann, and Richard Berndt — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, D-24118 Kiel, Germany

The interaction between magnetic adsorbates and Cooper pairs of a superconducting substrate leads to Yu-Shiba-Rusinov (YSR) resonances. This effect has so far been investigated with low-temperature scanning tunneling microscopy (STM) on adsorbates containing a metal atom, which provides the magnetic moment. We show that non-magnetic molecules without any metal ion can acquire a net magnetic moment upon assembly into clusters as evidenced by YSR resonances. The magnetic moment is due to a partial filling of the lowest unoccupied molecular orbital of the adsorbed molecules. We show that the filling and the corresponding magnetic moment depend on the number of neighboring molecules, on their relative orientations, and on the positions of hydrogen atoms in neighboring molecules. The YSR resonances are due to fractional charges that we analyze using an Anderson-like model.

Support via the European Union's Horizon 2020 research and innovation programme (766726) is acknowledged.

MA 64.3 Fri 11:00 GER 38

Tunneling of Cooper pairs through a molecular junction — Cristina Mier[1], Rose Reina[1], Leonard Garnier[2], Benjamin Verlhac[2], Laurent Limot[2], Nicolas Lorente[1], and •Deung-Jang Choi[1] — [1]Centro de Física de Materiales (MPC) CSIC-EHU San Sebastián, Spain — [2]Université de Strasbourg, CNRS, IPCMS, UMR 7504 Strasbourg, France

The tunneling of Cooper pairs between two superconductors connected through a weak link is called Josephson effect. Cooper pairs tunnel through Andreev bound states (ABS) which is localized to the weak link. The dependence of the ABS on the phase difference between the two superconductors fixes the way the Cooper pairs tunnel. ABS are a characteristic of the junction and they cannot be probed by varying the bias between the two superconductors since they take place at zero bias. This is very different from Yu-Shiba-Rusinov (YSR) in-gap state that can take place already for one superconductor and are due to the weakening of Cooper pairs produced by a magnetic impurity [1]. We will present experimental data and theoretical analysis characterizing the ABS of a reproducible Scanning Tunneling Microscope molecular junction giving us access to the elusive phase difference in an STM setup.

[1] Choi, D.-J. et al. Mapping the orbital structure of impurity bound states in a superconductor. Nat. Commun. 8, 15175 (2017).

MA 64.4 Fri 11:15 GER 38

Charge transport between discrete superconducting bound states at the atomic scale — •Haonan Huang[1], Ciprian Padurariu[2], Jacob Senkpiel[1], Robert Drost[1], Björn Kubala[2], Juan Carlos Cuevas[3], Alfredo Levy Yeyati[3], Joachim Ankerhold[2], Klaus Kern[1,4], and Christian R. Ast[1] — [1]MPI für Festkörperforschung, Stuttgart, Germany — [2]Institut für komplexe Quantensysteme, Universität Ulm, Ulm, Germany — [3]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [4]EPFL, Switzerland

A Yu-Shiba-Rusinov (YSR) state is a pair of in-gap states resulting from the interaction of magnetic atoms with a superconductor. While YSR states have received intensifying attention especially in the field of scanning tunneling microscopy (STM) due to its capability to resolve and measure the transport through single atom, the tunneling processes between YSR states still remain elusive. We are now able to controllably introduce YSR state of desired properties to the apex of the STM tip and measure the tunneling between the tip YSR state and a sample YSR state, which we call *Shiba-Shiba tunneling.* This results in a current peak at the sum of the two YSR energies. We observe a blockade in Shiba-Shiba peak when increasing conductance, which renders YSR tip a general probe of the single level lifetime at the atomic scale.

MA 64.5 Fri 11:30 GER 38

Theory of Shiba-Shiba tunneling at the edge of a Majorana chain — •Ciprian Padurariu[1], Haonan Huang[2], Björn Kubala[1], Christian R. Ast[2], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

The realization of the Majorana chain [1], a 1D-chain of Yu-Shiba-Rusinov (YSR) states created by magnetic impurities on the surface of a superconductor, suggests that Majorana states emerging at the edges can be probed by the STM.

Recently, we have developed an ideal tool to probe and manipulate the edge states of a Majorana chain. It consists of a superconducting STM tip with its own in-gap YSR state created by a magnetic impurity on the tip. With this device we have studied the sharp resonant transport between the YSR state on the tip and another one on the superconducting sample, and have developed its theory.

This talk will expand on the theory of Shiba-Shiba tunneling and present the possible opportunities to manipulate edge states of the Majorana chain. We discuss the effects of spin-orbit coupling on tunneling, that may be relevant to the experimental realization. In certain parameter regimes theory predicts that the edge state will transfer from the chain to the tip. This may provide a first step towards realizing braiding of edge states using the STM.

[1] S. Nadj-Perge, I. K. Drozdov, J. Li, H. Chen, S. Jeon, J. Seo, A.H. MacDonald, B.A. Bernevig, A. Yazdani, Science **346**, 602 (2014).

MA 64.6 Fri 11:45 GER 38

Bloch-type spin helix in bilayer Fe islands on Ir(110) by spin polarized STM — Jeison A. Fischer[1], •Timo Knispel[1], Mahasweta Bagchi[1], Jens Brede[1], Vasily Tseplyaev[2], Markus Hoffmann[2], Stefan Blügel[2], and Thomas Michely[1] — [1]II. Physikalisches Institut, Universität zu Köln, 50937 Cologne, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Most work on interfacial chiral spin textures focused on films exhibiting C3v symmetry and isotropic Dzyaloshinskii-Moriya interaction (DMI), known to only support Néel-type spin helices and skyrmions [1]. In contrast, C2v symmetry systems such as the (110) surface of an fcc crystal, are predicted to show anisotropic DMI leading to various scenarios of topological pattern formation [2]. Fully unexpectedly, our spin-polarized STM/STS study reveals a magnetic stripe phase, due to a spin helix with a period of 1.2 nm along the [-1 1 0] direction in bilayer Fe islands on unreconstructed Ir(110). Based on detailed field dependent measurements with a vector magnet, we conclude that the chirality of the spin helix is of Bloch-type, where the rotation is perpendicular with the propagation direction. This contradicts the assumption of the spin helix being induced by an interface in-plane DMI vector. Combined with theoretical insights, we discuss our findings in terms of the formation energy in systems with C2v symmetry. Funding: CRC1238 and the Jülich Supercomputing Center project CJIAS1F

[1] S. Heinze et al. Nat. Phys. Vol.7, p.713 (2011).
[2] M. Hoffmann et al. Nat. Commun. Vol.8, p.308 (2017).

MA 64.7 Fri 12:00 GER 38

Study of the skyrmion formation on Co monolayers deposited on superconducting Ru(0001) substrate — •Loic Mougel[1], Julian Skolaut[1], Marie Hervé[1,2], Timofey Balashov[1], Jasmin Jandke[1], Bertrand Dupé[3], and Wulf Wulfhekel[1] — [1]Physikalisches Institut ,KIT, Karlsruhe, Germany — [2]Institut des Nanosciences de Paris, CNRS, Sorbonne université, Paris, France — [3]Institute of Physics, Johannes Gutenberg-Universität (JGU), Mainz, Allemagne

It has been theoretically proposed in the last years that magnetic skyrmions, when positioned in proximity to a superconductor might host Majorana bound states. These states are predicted to appear in pair of entangled states, as a zero-energy excitation in a superconducting gap. Such states are of great interest for the realization of Topological Quantum Computation.

Recently we demonstrated that it was possible to stabilize skyrmions using low magnetic field, on monolayers of Co deposited on a Ru(0001) surface. By submitting the system to a magnetic field one can create skyrmions that will remain meta-stable in the remanent state. In this communication we report on the preliminary experiments realized on the Co monolayers deposited on the superconducting Ru(0001) surface. We will present the measurements of Ruthenium superconducting gap, as well as the study of the proximity effect that arise at the Ferromagnetic/Superconductor interface, and how the superconducting state can influence the spin-spiral structure.

MA 64.8 Fri 12:15 GER 38

Theoretical description of single-Co Kondo effect in atomic Cu wires on Cu(111) — Nicolas Néel[1], Markus Bohn[1], Jörg Kröger[1], •Malte Schüler[2,3], Bin Shao[2,3], Tim Wehling[2,3], Alexander Kowalski[4], and Giorgio Sangiovanni[4] — [1]Institute for Physics, Technical University of Ilmenau — [2]Bremen Center for Computational Materials Science, University Bremen, — [3]Institute for Theoretical Physics, University Bremen — [4]Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat, University of Würzburg

Linear atomic chains containing a single Kondo atom, Co, and several nonmagnetic atoms, Cu, assembled atom by atom on Cu(111) with the tip of a scanning tunneling microscope show a peculiar evolution of the Kondo resonance. The evolution of this resonance can be inferred from changes in the line shape of the Abrikosov-Suhl-Kondo resonance. Strikingly, for two geometries no Kondo resonance at all is observed. We perform state-of-the-art first-principles calculations to describe the resonance and unravel possible microscopic origins of the remarkable experimental observations. We focus on the fact that the theoretical results are in line with experimental findings for all but two geometries which show no resonance and draw conclusions on the current state of theoretical description of many-body phenomena in real materials.

MA 64.9 Fri 12:30 GER 38

Ensembles of Orbital Memories on Black Phosphorus —

•Elze Knol[1], Brian Kiraly[1], Hilbert Kappen[2], and Alexander Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Donders Institute for Neuroscience, Radboud University, Nijmegen, The Netherlands

Cobalt atoms at the surface of black phosphorus (BP) have demonstrated bistable valencies [1], which can be utilized to store digital information. According to density functional theory calculations, each valency hosts a unique magnetic moment. The calculations further reveal that the bistable valencies arise due to a vertical atom displacement which modifies the screening from the underlying BP. In order to study the role of this screening, we take advantage of the tip-induced band bending occurring at the tip-sample junction of a scanning tunneling microscope to probe the energy landscape governing the valency stability. We find, both in single atom memories and ensembles of atomic memories, that the effects of local band bending are depending on the black phosphorus surface. We visualize this dependency directly with a scanning tunneling microscope by carefully studying the position dependence of the stochastic current noise. The inherent properties of this system [2] provide a unique opportunity for atomic ensembles in solids.

[1] Kiraly, et. al., Nature Commun. 9, 3904, (2018). [2] Kiraly, et. al., Phys. Rev. Lett. 123, 216403, (2019).

MA 64.10 Fri 12:45 GER 38

Efficient Ab-initio Multiplet Calculations for Magnetic Adatoms on MgO — •Christoph Wolf[1], Fernando Delgado[2], Jose Reina[3], and Nicolas Lorente[3] — [1]Center for Quantum Nanoscience, Seoul, Korea — [2]Universidad de La Laguna, Spain — [3]Centro de Fisica de Materiales CFM/MPC, Spain

Scanning probe microscopy and spectroscopy, and more recently in combination with electron spin resonance, have allowed the direct observation of electron dynamics on the single-atom limit. The interpretation of data is strongly depending on model Hamiltonians. However, fitting effective spin Hamiltonians to experimental data lacks the ability to explore a vast number of potential systems of interest.

By using plane-wave density functional theory (DFT) as starting point, we build a multiplet Hamiltonian making use of maximally-localized Wannier functions. The Hamiltonian contains spinorbit and electron-electron interactions needed to obtain the relevant spin dynamics. The resulting reduced Hamiltonian is solved by exact diagonalization. We compare three prototypical cases of 3d transition metals Mn (total spin S=5/2), Fe (S=2) and Co (S=3/2) on MgO with experimental data and find that our calculations can accurately predict the spin orientation and anisotropy of the magnetic adatom. Our method does not rely on experimental input and permits us to explore and predict the fundamental magnetic properties of adatoms on surfaces.

MA 64.11 Fri 13:00 GER 38

Probing the magnetism of single atoms with orbital sensitivity — Aparajita Singha[1,2], Daria Sostina[1,2], Christoph Wolf[1,2], Safa Ahmed[1,2], Denis Krylov[1,2], Luciano Colazzo[1,2], Alessandro Barla[3], Pierluigi Gargiani[4], Stefano Agrestini[4], Woo-suk Noh[5], Marina Pivetta[6], Stefano Rusponi[6], Harald Brune[6], Andreas J. Heinrich[1,2], and •Fabio Donati[1,2] — [1]Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul, Republic of Korea — [2]Department of Physics, Ewha Womans University, Seoul, Republic of Korea — [3]Istituto di Struttura della Materia (ISM), Consiglio Nazionale delle Ricerche (CNR), Trieste, Italy — [4]ALBA Synchrotron Light Source, Cerdanyola del Vallès, Catalonia, Spain — [5]Pohang University of Science and Technology, Pohang, Republic of Korea — [6]Institute of Physics, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Individual Ho atoms adsorbed on MgO/Ag(100) show large magnetic anisotropy and long magnetic lifetime up to 40 K [Science 352, 318 (2016)]. Investigating the distribution of the electron spins among the valence orbitals is crucial to understand the quantum level structure and the origin of magnetic stability in these atoms. Here, we use the orbital sensitivity of x-ray absorption spectroscopy to investigate the valence magnetism of rare earth atoms and clusters on MgO/Ag(100). We find both Gd and Ho atoms in a monovalent state, with one electron transferred to the underneath substrate. Combining our findings with density functional theory, we clarify the controversy on the ground state of Ho single atom magnets [Phys. Rev. Lett. 121, 027201 (2018)].

MA 64.12 Fri 13:15 GER 38

Quantum stochastic resonance of single Fe atoms — •Max Hänze[1,2], Gregory McMurtrie[1], Luigi Malavolti[1,2], and Sebastian Loth[1,2] — [1]University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Stochastic resonance [1] can be observed in a variety of different systems, ranging from the periodicity of glacial periods in paleontology [2] to the time-dependent behavior of individual neurons [3] in the field of neuroscience. All such systems exhibit stochastic behavior which, because of a strong nonlinear response, can be synchronized to a small harmonic excitation. We observe quantum stochastic resonance in a single Fe atom deposited on the copper nitride surface [4] using scanning tunneling microscopy. Unlike in standard stochastic resonance, the atomic-scale process is dominated by quantum fluctuations where the magnetic state of the Fe atom is driven resonantly between two states in a classically forbidden regime. This phenomenon enables the direct observation of spin dynamics in open quantum system.

[1] R. Benzi, J. Phys. A: Math. Gen 14, L453 (1981) [2] P. N. Pearson et al. Paleontological Society Papers 18, 1-38 (2012) [3] A. J. Bulsara et al. Theor. Biol. 152, 531-555 (1991) [4] C. F. Hirjibehedin et al. Science 317, 1199-1203 (2007)

MA 64.13 Fri 13:30 GER 38

Electronic transport properties in bidimensional ferromagnet GdAu2 with atomic scale resolution — •Alberto Moya[1,2,3], David Serrate[1,2], M. Ricardo Ibarra[1,2], and Matthias Bode[3] — [1]Instituto de Ciencia de Materiales de Aragón, CSIC-Universidad de Zaragoza, E-50009 Zaragoza, Spain — [2]Instituto de Nanociencia de Aragón, Universidad de Zaragoza, E-50018 Zaragoza, Spain — [3]Physikalisches Institut, Lehrstuhl für Experimentelle Physik 2, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Electronic properties of atomic scale motifs are difficult to measure because of complexity associated to patterning such small electrical probe contacts. In this work, we measure the electrical resistance of an antiphase boundary of a GdAu2 surface alloy. The GdAu2 monolayer is prepared on a Au(111) substrate and is known to be in-plane ferromagnetically ordered at low temperatures. It exhibits occasional antiphase boundaries which separate structurally identical but phase shifted domains by an atomically sharp 1D lattice defect. Here we measure the magnetotransport response across the boundary.

The measurements were performed by means of the recently developed Molecular Nanoprobe (MONA) technique. In this technique charge carriers (electrons or holes) are injected from the tip of a scanning tunneling microscope (STM) and detected by conformational switching processes excited inelastically by hot electrons reaching dehydrogenated phthalocyanine molecules. By statistically analyzing thousands of injection sequences the charge transport between two surface spots can be evaluated.