Magnetism Division
Fachverband Magnetismus (MA)

Michael Farle
Fakultät für Physik
Universität Duisburg-Essen
47057 Duisburg
fv-magnetismus-farle@uni-due.de

Overview of Invited Talks and Sessions

(Lecture rooms HSZ 01, 04, 101, 301, 401, and 403; Posters P2-EG, OG1, OG2, OG3, and OG4)

INNOMAG e.V. Dissertation Prize and Master/Diplom Prize 2017)

Monday 15:00–17:00 HSZ 01
Please attend!

Tutorial: Micromagnetic Simulations

MA 1.1	Sun	16:00–16:45	HSZ 401	**An overview of mumax3 with a spotlight on its newest features** — •Jonathan Leliaert
MA 1.2	Sun	16:45–17:30	HSZ 401	**Micromagnetics simulations with MicroMagnum and OMNeS** — •Kai Litzius
MA 1.3	Sun	17:45–18:30	HSZ 401	**Computational micromagnetics with JOOMMF** — •Hans Fangohr

PhD-Student Symposium "Quantum Magnets: Frustration and Topology in Experiment and Theory (jointly with young DPG (jDPG)": Invited Talks

MA 17.1	Tue	9:45–10:30	HSZ 04	**Frustrated Quantum Magnets: Theory** — •Matthias Vojta
MA 17.2	Tue	10:30–11:15	HSZ 04	**Ground State Selection in Quantum Pyrochlore Magnets** — •Bruce D. Gaulin
MA 17.3	Tue	11:30–12:00	HSZ 04	**Effects of anisotropic exchange in strong spin-orbit coupled magnets** — •Natalia Perkins
MA 17.4	Tue	12:00–12:30	HSZ 04	**Numerical Approaches to Frustrated Quantum Magnets** — •Stephan Rachel
MA 17.6	Tue	13:45–14:15	HSZ 04	**Nuclear Probes on Frustrated Magnets** — •Philippe Mendels
MA 17.7	Tue	14:15–14:45	HSZ 04	**Complex spin structures and multifunctional magnetism** — •Vivien Zapf

Invited Talks

MA 10.1	Mon	15:00–15:30	HSZ 04	**Magnetoelastic coupling and lattice dynamics in magnetocaloric materials** — •Markus Ernst Gruner
MA 22.1	Tue	9:30–10:00	HSZ 401	**Tuning the zero-point spin-fluctuations of single adatoms** — •Julen Ibañez-Azpiroz

Focus Session “Antiferromagnetic Spintronics”

MA 2.1	Mon	9:30–10:00	HSZ 01	**Electrical Control of Quantum Coherent Phenomena in Insulating Antiferromagnets** — •Arne Braatas

MA 2.2	Mon	10:00–10:15	HSZ 01	**Route towards topological antiferromagnetic spin-orbitronics** — •Libor Šmejkal
MA 2.3	Mon	10:15–10:45	HSZ 01	**Electronic and magnonic spin transport in antiferromagnets** — •Vincent Baltz
MA 2.4	Mon	11:00–11:30	HSZ 01	**Staggering antiferromagnetic domain wall velocity in a staggered spin-orbit field** — •Olena Gomonay
MA 2.6	Mon	11:45–12:15	HSZ 01	**Current induced switching of an antiferromagnet** — •Kevin W. Edmonds

Focus Session "Magnon Transport in Metallic Spin Textures"

MA 45.1	Wed	15:45–16:15	HSZ 04	**Manipulating Room Temperature Magnetic Skyrmions** — •Axel Hoffmann
MA 45.2	Wed	16:15–16:45	HSZ 04	**Spin wave caustics and channelling in chiral spin systems** — •Joo-Von Kim
MA 45.3	Wed	17:00–17:30	HSZ 04	**Snell's Law for Spin Waves** — •Johannes Stigloher
MA 45.4	Wed	17:30–17:45	HSZ 04	**Magnon-skyrmion scattering in chiral magnets** — •Markus Garst
MA 45.5	Wed	17:45–18:00	HSZ 04	**Frequency-division multiplexing in magnonic networks by spin-wave caustics** — •Frank Heussner

Focus Session "Magnetic Correlations in Mesoscopic Spin Structures"

MA 32.1	Wed	9:30–10:00	HSZ 01	**Collective modes in magnonic vortex crystals** — •Guido Meier
MA 32.2	Wed	10:00–10:30	HSZ 01	**Stability of interfacial Skyrmions, Solitons and Bound Monopoles: How to store Energy in topological magnetic Quasiparticles.** — •Elena Vedmedenko
MA 32.3	Wed	10:30–11:00	HSZ 01	**Exploring the statistical physics of frustrated spin systems with artificial spin ice** — •Ian Gilbert
MA 32.4	Wed	11:15–11:45	HSZ 01	**Skyrmions in [Pt/Co/Ir] multilayers at room temperature** — •Katharina Zeissler
MA 32.5	Wed	11:45–12:15	HSZ 01	**Artificial magnets as model systems : from the fragmentation of magnetization to the seminal square ice model** — •Benjamin Canals

Focus Session "Topology meets Magnetism"

MA 53.1	Thu	15:00–15:30	HSZ 01	**Topological phases for magnons and electrons in the skyrmion lattice** — •Joaquín Fernandez-Rossier
MA 53.2	Thu	15:30–16:00	HSZ 01	**Thermal Hall Effect of Spin Excitations in Quantum Magnets** — •Max Hirschberger
MA 53.3	Thu	16:15–16:45	HSZ 01	**Magnon-mediated Dzyaloshinskii-Moriya torques, heat pumping, and spin Nernst effect** — •Alexey Kovalev
MA 53.4	Thu	16:45–17:15	HSZ 01	**Magnon companion pieces to electronic topological materials** — •Alexander Mook
MA 53.5	Thu	17:15–17:45	HSZ 01	**Nonreciprocal propagation of elementary excitations in noncentrosymmetric magnets** — •Yoshinori Onose

Invited talks of the joint symposium SYCE

See SYCE for the full program of the symposium.

SYCE 1.1	Mon	15:00–15:30	HSZ 02	**Ferroelectric domain walls: from conductors to insulators and back again** — •Petro Maksymovych
SYCE 1.2	Mon	15:30–16:00	HSZ 02	**Zoology of skyrmions and the role of magnetic anisotropy in the stability of skyrmions** — •Istvan Kezsmarki, Sandor Bordacs, Jonathan White, Vladimir Tsurkan, Alois Loidl, Peter Milde, Hiroyuki Nakamura, Andrey Leonov
SYCE 1.3	Mon	16:00–16:30	HSZ 02	**Magnetic imaging of topological phenomena in ferroic materials** — •Weida Wu

SYCE 1.4	Mon	17:00–17:30	HSZ 02	**Topological skyrmion textures in chiral magnets** — •Markus Garst
SYCE 1.5	Mon	17:30–18:00	HSZ 02	**Learning through ferroelectric domain dynamics in solidstate synapses** — Sören Boyn, Gwendal Lecerf, Stéphane Fusil, Sylvain Saïghi, Agnès Barthélémy, Julie Grollier, Vincent Garcia, •Manuel Bibes

Invited talks of the joint symposium SYES

See SYES for the full program of the symposium.

SYES 1.1	Fri	10:30–11:00	HSZ 02	**Going Beyond Conventional Functionals with Scaling Corrections and Pairing Fluctuations** — •Weitao Yang
SYES 1.2	Fri	11:00–11:30	HSZ 02	**Multi-reference density functional theory** — •Andreas Savin
SYES 1.3	Fri	11:30–12:00	HSZ 02	**Density functionals from machine learning** — •Kieron Burke
SYES 1.4	Fri	12:00–12:30	HSZ 02	**Taming Memory-Dependence in Time-Dependent Density Functional Theory** — •Neepa Maitra
SYES 1.5	Fri	12:30–13:00	HSZ 02	**Quantum Embedding Theories** — •Fred Manby

Sessions

MA 1.1–1.3	Sun	16:00–18:30	HSZ 401	**Tutorial: Micromagnetic Simulations**
MA 2.1–2.6	Mon	9:30–12:15	HSZ 01	**Focus Session: Antiferromagnetic Spintronics**
MA 3.1–3.12	Mon	9:30–12:45	HSZ 101	**Magnetic Textures: Statics and experimental imaging**
MA 4.1–4.13	Mon	9:30–13:00	HSZ 204	**Transport: Topological Insulators (jointly with DS, MA, HL, O)**
MA 5.1–5.10	Mon	9:30–12:15	HSZ 401	**Magnetization/Demagnetization Dynamics**
MA 6.1–6.9	Mon	9:30–11:45	HSZ 403	**Magnetic Instrumentation and Characterization**
MA 7.1–7.9	Mon	10:00–13:00	MER 02	**Analytical Electron Microscopy: SEM and TEM-based Material Analysis**
MA 8.1–8.4	Mon	10:30–12:10	HSZ 04	**SKM Dissertation-Prize 2017**
MA 9.1–9.5	Mon	15:00–18:00	HSZ 02	**Novel Functionality and Topology-Driven Phenomena in Ferroics and Correlated Electron Systems (DF with MA, KR, MI, TT and DS)**
MA 10.1–10.12	Mon	15:00–18:30	HSZ 04	**Caloric Effects in Ferromagnetic Materials**
MA 11	Mon	15:00–17:00	HSZ 101	**INNOMAG e.V. Dissertationspreis und Diplom-/Masterpreis 2017**
MA 12.1–12.12	Mon	15:00–18:15	HSZ 204	**Transport: Graphene and Carbon Nanostructures (jointly with DY, DS, HL, MA, O)**
MA 13.1–13.11	Mon	15:00–18:00	HSZ 304	**Transport: Topological Phases (jointly with DS, MA, HL, O)**
MA 14.1–14.9	Mon	15:00–17:30	HSZ 401	**Magnetization / Demagnetization Dynamics II**
MA 15.1–15.13	Mon	15:00–18:30	HSZ 403	**Magnetic Heuslers, Half-metals and Oxides (jointly with TT)**
MA 16.1–16.5	Mon	17:30–18:45	HSZ 401	**Spin Dynamics: Magnetic relaxation and Gilbert Damping**
MA 17.1–17.8	Tue	9:30–15:00	HSZ 04	**PhD Symposium: Quantum Magnets: Frustration and Topology in Experiment and Theory (jointly with Young DPG (jDPG)**
MA 18.1–18.14	Tue	9:30–13:15	HSZ 103	**Transport: Quantum Coherence and Quantum Information Systems - Theory (jointly with MA, HL)**
MA 19.1–19.8	Tue	9:30–11:45	HSZ 201	**Transport: Topological Semimetals 1 (jointly with DS, MA, HL, O)**
MA 20.1–20.13	Tue	9:30–13:00	HSZ 301	**Bio- and Molecular Magnetism**
MA 21.1–21.13	Tue	9:30–13:00	HSZ 304	**Correlated Electrons: Frustrated Magnets - Strong Spin-Orbit Coupling 1**
MA 22.1–22.10	Tue	9:30–12:30	HSZ 401	**Surface Magnetism (Joint Session with O)**
MA 23.1–23.10	Tue	9:30–12:15	HSZ 403	**Spin Dynamics and Transport: Ultrafast Effect**
MA 24.1–24.6	Tue	9:30–12:20	GER 37	**Focus: Microwave and THz Properties, Developments and Applications of Dielectric Materials**
MA 25.1–25.13	Tue	9:30–13:30	WIL B321	**Ferroics - Domains, Domain Walls and Skyrmions I**

MA 26.1–26.8	Tue	14:00–16:00	HSZ 101	**Thin Films: Magnetic Coupling Phenomena / Exchange Bias**
MA 27.1–27.7	Tue	14:00–15:45	HSZ 301	**Spintronics (incl. Quantum Dynamics)**
MA 28.1–28.7	Tue	14:00–15:45	HSZ 401	**Spin Dynamics and Transport: Domain Walls**
MA 29.1–29.5	Tue	14:00–15:15	HSZ 403	**Spin dependent Transport Phenomena**
MA 30.1–30.8	Tue	18:30–20:30	P1A	**Electronic structure of Surfaces: Magnetism and Spin Phenomena**
MA 31.1–31.7	Tue	18:30–20:30	P2-EG	**Ultrafast Electron and Spin Dynamics**
MA 32.1–32.5	Wed	9:30–12:15	HSZ 01	**Focus Session: Magnetic Correlations in Mesoscopic Spin Structures**
MA 33.1–33.13	Wed	9:30–13:00	HSZ 03	**Transport: Quantum Coherence and Quantum Information Systems - Experiment (jointly with MA, HL)**
MA 34.1–34.13	Wed	9:30–13:00	HSZ 04	**Spin Dynamics and Transport: Magnonics**
MA 35.1–35.13	Wed	9:30–12:45	HSZ 101	**Magnetic Particles / Clusters**
MA 36.1–36.12	Wed	9:30–12:45	HSZ 201	**Transport: Molecular Electronics and Photonics (jointly with CPP, HL, MA, O)**
MA 37.1–37.11	Wed	9:30–12:30	HSZ 401	**Micro- and Nanostructured Magnetic Materials**
MA 38.1–38.10	Wed	9:30–12:15	HSZ 403	**Electron Theory of Magnetism and Correlations**
MA 39.1–39.6	Wed	9:30–11:30	MER 02	**X-Ray Imaging, Holography, Ptychography and Tomography**
MA 40.1–40.1	Wed	15:00–15:30	HSZ 04	**Walter Schottky Prize Award (PV IX)**
MA 41.1–41.11	Wed	15:00–18:00	HSZ 101	**Micromagnetism / Computational Magnetics**
MA 42.1–42.10	Wed	15:00–17:45	HSZ 204	**Transport: Topological Semimetals 2 (jointly with DS, MA, HL, O)**
MA 43.1–43.10	Wed	15:00–18:00	HSZ 401	**Topological Insulators I (jointly with DS, HL, O, TT)**
MA 44.1–44.9	Wed	15:00–17:30	HSZ 403	**PhD Symposium Quantum Magnets (contributed talks)**
MA 45.1–45.5	Wed	15:45–18:00	HSZ 04	**Focus Session: Magnon Transport in Metallic Spin Textures**
MA 46.1–46.8	Thu	9:30–13:00	HSZ 03	**Focus Session on 2D Materials: Ballistic Quantum Transport in Graphene (jointly with DY, DS, HL, MA, O)**
MA 47.1–47.14	Thu	9:30–13:15	HSZ 04	**Spin Hall Effects and Skyrmions I**
MA 48.1–48.14	Thu	9:30–13:15	HSZ 101	**Spin Dynamics and Transport: Spin Excitations and Spin Torque Phenomena**
MA 49.1–49.11	Thu	9:30–12:30	HSZ 401	**Surface Magnetism 2 (Joint Session with O)**
MA 50.1–50.9	Thu	9:30–12:00	HSZ 403	**Spincaloric Transport (jointly with TT)**
MA 51.1–51.10	Thu	9:30–12:45	POT 251	**Topological Insulators I (joined session with TT)**
MA 52.1–52.6	Thu	14:45–16:45	POT 251	**Topological Insulators II (joined session with TT)**
MA 53.1–53.5	Thu	15:00–17:45	HSZ 01	**Focus Session: Topology meets Magnetism**
MA 54.1–54.11	Thu	15:00–18:00	HSZ 04	**Spin Hall Effects and Skyrmions II**
MA 55.1–55.11	Thu	15:00–18:00	HSZ 101	**Thin Films: Magnetic Anisotropy**
MA 56.1–56.11	Thu	15:00–18:00	HSZ 403	**Bulk Materials: Soft and hard permanent magnets**
MA 57.1–57.8	Thu	15:00–17:15	WIL B321	**Multiferroics (DF and MA)**
MA 58.1–58.8	Fri	9:30–11:30	HSZ 03	**Transport: Spintronics, Spincalorics and Magnetotransport (jointly with DS, HL, MA)**
MA 59.1–59.8	Fri	9:30–11:30	HSZ 04	**Topological Insulators II (jointly with DS, HL, O, TT)**
MA 60.1–60.10	Fri	9:30–12:00	HSZ 101	**Magnetic Materials: Applications and Multielement Bulk Materials**
MA 61.1–61.8	Fri	9:30–11:30	HSZ 401	**Skyrmion Dynamics**
MA 62.1–62.8	Fri	9:30–11:45	HSZ 403	**Magnetic Imaging (Experimental Techniques)**
MA 63.1–63.10	Fri	9:30–12:30	POT 251	**Topological Insulators III (joined session with TT)**
MA 64.1–64.69	Fri	9:30–13:00	P2-EG	**Poster 1**
MA 65.1–65.31	Fri	9:30–13:00	P2-OG1	**Poster 2**
MA 66.1–66.27	Fri	9:30–13:00	P2-OG2	**Poster 3**
MA 67.1–67.30	Fri	9:30–13:00	P2-OG3	**Poster 4**
MA 68.1–68.28	Fri	9:30–13:00	P2-OG4	**Poster 5**
MA 69.1–69.5	Fri	10:30–13:00	HSZ 02	**Frontiers of Electronic-Structure Theory: New Concepts and Developments in Density Functional Theory and Beyond**

General Meeting of the Magnetism Division (Fachverband Magnetismus)

Thursday 18:00–19:00 HSZ 04
All members of the Magnetism Section are invited to participate!

MA 1: Tutorial: Micromagnetic Simulations

Organizers: Karin Everschor, Pedram Bassirian (Johannes Gutenberg Universität Mainz)

In the field of spintronics, micromagnetic simulations are an essential tool to predict new and explain existing phenomena. Nowadays various micromagnetic simulation softwares based on different solving techniques are available and they have accelerated research in different fields of spintronics. The goal of this tutorial is to provide a broad overview of different codes available and of what they are capable of doing. In particular it should be highlighted where the different simulators are good at. With this tutorial we aim to improve the general understanding and applicability of micromagnetic simulations and encourage people to use them more frequently and accurately in their research.

Time: Sunday 16:00–18:30 Location: HSZ 401

Tutorial MA 1.1 Sun 16:00 HSZ 401

An overview of mumax3 with a spotlight on its newest features — Arne Vansteenkiste[1], •Jonathan Leliaert[1], Mykola Dvornik[2], Mathias Helsen[1], Felipe Garcia-Sanchez[3], and Bartel Van Waeyenberge[1] — [1]Ghent University, Ghent, Belgium — [2]University of Gothenburg, Gothenburg, Sweden — [3]INRIM, Turin, Italy

In this talk an overview is given of the GPU-accelerated micromagnetic software package MuMax3, developed at the DyNaMat group at Ghent University. This software solves the time- and space dependent evolution of the magnetization on the nano- to micro scale using a finite-difference discretization. Its high performance and low memory requirements allow for large-scale simulations to be performed in limited time and on inexpensive hardware. We begin with a short introduction to micromagnetism. Next, with the help of live demos, it is shown how to use this software either in its user-friendly web-interface, or via input-files for more complex simulations. Finally, we introduce three new features: first, mumax3-server allows to share simulations between different computers to efficiently execute large batches of simulations. Second, the adaptive time-step algorithm was extended to also simulate nonzero temperatures with optimal performance. Third, we present the possibility to include custom energy terms increases the users* freedom to add more *exotic* energy terms, not present in standard packages, to their simulations.

Tutorial MA 1.2 Sun 16:45 HSZ 401

Micromagnetics simulations with MicroMagnum and OMNeS — •Kai Litzius and Matthias Sitte — Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany

The open-source micromagnetics simulator package MicroMagnum is a collaborative effort of the University of Hamburg and JGU Mainz. Based on the phenomenological Landau-Lifschitz-Gilbert equation, its core is intimately connected to experiments, aiding in their interpretation and analysis. In its current version, MicroMagnum comes with a complete set of modules to describe phenomenologically magnetic systems in terms of exchange interaction, magnetocristalline anisotropies, external and magnetostatic fields, spin torques, etc. MicroMagnum has a robust and modular architecture that aims to combine the speed and flexibility of C++ together with the usability of the Python scripting language and allows to use both CPU- and GPU-based multithreaded computing, thereby gaining efficiency on regular grids compared to traditional packages such as OOMMF. It can be easily extended by the user through additional modules such as Dzyaloshinskii-Moriya interaction with arbitrary symmetries (to be released).

In the second part, we present OMNeS as a new, open source environment currently under development in the INSPIRE group at the JGU Mainz. OMNeS uses finite-element methods on unstructured grids as complementary approach to MicroMagnum, thereby allowing us to simulate large real-world devices capable of computing multiple device characteristics in a multi-scale and self-consistent manner.

15 min. break

Tutorial MA 1.3 Sun 17:45 HSZ 401

Computational micromagnetics with JOOMMF — •Hans Fangohr and Marijan Beg — University of Southampton, SO17 1BJ, Southampton, United Kingdom

Computational micromagnetic studies complement experimental and theoretical studies, and are at times the only feasible way to address research challenges, effective industrial design and engineering of various products and systems. In this talk, we will introduce computational micromagnetics by using our Python interface to drive OOMMF, which is likely the most widely used micromagnetic simulation package. A major advantage of this interface is that OOMMF simulation runs are embedded in a general purpose programming language which enables the full use of the ecosystem of scientific libraries available for Python. For example, design optimisation, specialised post-processing, and visualisation can all be carried out in a single script, which significantly contributes to the reproducibility of micromagnetic research. This project is a part of the Jupyter-OOMMF (JOOMMF) activity in the OpenDreamKit project and we acknowledge financial support from Horizon 2020 European Research Infrastructures project (676541). The work is also supported by the EPSRC CDT in Next Generation Computational Modelling EP/L015382/1, and the EPSRC grants EP/M022668/1 and EP/N032128/1.

MA 2: Focus Session: Antiferromagnetic Spintronics

Organized by Karin Everschor-Sitte and Jairo Sinova (Johannes Gutenberg Universität Mainz)

The common view of antiferromagnets as *interesting but useless* materials was verbalized by Louis Ne*el in his 1970 Nobel lecture on the discovery of antiferromagnetism. This view has changed a lot in recent years as antiferromagnets are becoming active elements in spintronic devices. The established knowledge in ferromagnets has allowed for rapid theoretical developments and a lot of successes recently in this field of research. An antiferromagnet is by far more than just two coupled ferromagnets and thus allows for new features. When highlighting differences between antiferromagnets and ferromagnets, one has to mention, that i) all effects in antiferromagnets are enhanced due to antiferromagnetic exchange coupling and ii) antiferromagnets obey a different current induced dynamics, namely inertia-like instead of the gyroscopic-like ferromagnetic dynamics. In addition, its natural coupling to Dirac fermion physics makes them good candidates to explore topological properties in these materials from novel perspectives. The goal of this Focus Session is to bring together the leading scientist in the field of antiferromagnetic spintronics and exploit further their potential of applications.

Time: Monday 9:30–12:15 Location: HSZ 01

Invited Talk MA 2.1 Mon 9:30 HSZ 01

Electrical Control of Quantum Coherent Phenomena in Insulating Antiferromagnets — •Arne Braatas — Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

Usually, antiferromagnets only function as passive spintronics components. However, antiferromagnets' markedly different properties as compared to ferromagnets make them interesting and attractive in a more dynamic role. Furthermore, in insulators, there are no moving charges involved so that the power reduction can be significant.

Antiferromagnetic insulators couple strongly to electric currents in adjacent normal metals. Therefore, antiferromagnets can fulfill the role as active components in spintronics devices despite their lack of a macroscopic magnetic moment, and even when they are insulating.

We explore routes for electrical control of quantum coherent magnon phenomena in insulating antiferromagnets.

First, we describe the formation of steady-state magnon condensates controlled by a spin accumulation in adjacent normal metals. Spin-transfer by this spin accumulation affects the staggered field of the antiferromagnet. The resulting condensation may occur even at room temperature when the spin transfer to the metal is faster than the relaxation processes in the antiferromagnet.

Second, we will discuss how antiferromagnets may exhibit long-range spin superfluidity in insulators, which studies indicate are good spin conductors. The spin superfluidity can be detected in non-local geometries and can reach several micrometers.

MA 2.2 Mon 10:00 HSZ 01

Route towards topological antiferromagnetic spin-orbitronics — •Libor Šmejkal[1,2], Jairo Sinova[1,2], and Tomáš Jungwirth[2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Institute of Physics of the Czech Academy of Sciences, CZ-16253 Prague, Czech Republic

We present our recent theoretical predictions of topologically nontrivial antiferromagnets (AF) useful for spin-orbitronics. We start with derivation of symmetry criteria and minimal models for the nontrivial bulk and surface topologies in AF. We identify real material candidates by using the first-principles calculations, e.g. CuMnAs.[1]

We discuss in detail an emergent electric control of Dirac fermions by Néel spin orbit torques (NSOT) in an AF preserving the combination of spatial and time inversion symmetry.[1] We explain physical mechanism of the control of the bands-topology by tuning the nonsymmorphic crystal symmetry via the staggered order reorientation. We reveal the necessary criteria to accommodate Dirac quasi-particles and NSOT simultaneously in single material platform.

In the last part we demonstrate the merits of Dirac and Weyl fermions for spin-orbitronics transport effects in collinear and noncollinear AF by first-principles calculations. We suggest novel magneto-transport effects, for instance topological anisotropic magnetoresistance (AMR). We propose experimental setup for the observation of the topological AMR as clear signature of Dirac fermions.

[1] L. Šmejkal et al., eprint arXiv:1610.08107 (2016)

Invited Talk MA 2.3 Mon 10:15 HSZ 01

Electronic and magnonic spin transport in antiferromagnets — Lamprini Frangou[1], Guillaume Forestier[1], Stephane Auffret[1], Serge Gambarelli[2], and •Vincent Baltz[1] — [1]SPINTEC (Univ. Grenoble Alpes / CNRS / INAC-CEA), F-38000 Grenoble, France — [2]SYMMES (Univ. Grenoble Alpes / INAC-CEA), F-38000 Grenoble, France

Through spin-pumping experiments we investigated how spin currents can be injected, transmitted and converted in antiferromagnets and what is the influence of the magnetic order. Spin pumping results from the magnetization dynamics of a ferromagnetic spin injector, which pumps a spin current into an adjacent spin sink. This spin sink filters, absorbs and converts the current to an extent which depends on its interface and bulk spin-dependent properties. This can be recorded either through the changes induced in ferromagnetic damping or through direct electrical means by measuring the inverse spin Hall effect. Whether the transport regime is electronic or magnonic depends of the electrical nature of the spin-sink and how strongly injector and sink are coupled. Due to magnetic coupling transfer/sink and propagation of spin angular momentum involves magnons from the oscillating ferromagnet feeding into the antiferromagnet. Measurements of the spin penetration were obtained for several antiferromagnetic metals and insulators. Interestingly, spins propagate more efficiently in layers where the magnetic order is fluctuating rather than static. Magnonic spin transport is also more efficient than its electronic counterpart. The experimental data were compared to some of the recently developed theories.

15 min. break

Invited Talk MA 2.4 Mon 11:00 HSZ 01

Staggering antiferromagnetic domain wall velocity in a staggered spin-orbit field — •Olena Gomonay — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Future applications of antiferromagnets (AFs) in many spintronics devices rely on the precise manipulation of domain walls. Here we discuss different approaches to manipulate and control the domain walls in AF. We demonstrate the possibility to drive an AF domain-wall at high velocities by field-like Néel spin-orbit torques. Such torques arise from the current-induced local fields that alternate their orientation on each sub-lattice of the AF and whose orientation depend primarily on the current direction, giving them their field-like character. The domain-wall velocities that can be achieved by this mechanism are two orders of magnitude greater than the ones in ferromagnets. This arises from the efficiency of the staggered spin-orbit fields to couple to the order parameter and from the exchange-enhanced phenomena in AF texture dynamics, which leads to a low domain-wall effective mass and the absence of a Walker break-down limit. We also discuss other possibilities based on application of spin-polarised current and/or time-dependent magnetic field. We believe that our approaches pave a way for the development of AF-based devices based on controlled motion of AF domain walls.

MA 2.5 Mon 11:30 HSZ 01

Terahertz spectroscopy of femtosecond spins currents in magnetic heterostructures — •Tom Seifert and Tobias Kampfrath — Fritz Haber Institut, MPG, Berlin, Deutschland

Spin-orbit interaction (SOI) will be of central importance for future spin-based electronics (spintronics) as it permits, for example, the conversion of charge into spin currents and vice versa via the spin Hall effect [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 pulses to trigger ultrafast spin transport in magnetic thin-film stacks. Due to SOI, the spin current is partially converted into a transverse charge current which is monitored by detecting the concomitantly emitted THz electromagnetic radiation [2,3]. In particular, we study THz emission from bilayers consisting of a magnetic and a nonmagnetic metallic layer. By varying the magnetic layer material from conducting to insulating and from ferromagnetic to antiferromagnetic, we aim at identifying the different mechanisms that can lead to the ultrafast generation of spin currents across those structures.

The results shown here were obtained in close collaborations with the research groups of J. Barker, C. Ciccarelli, M. Kläui, Y. Mokrousov, M. Münzenberg, P.M. Oppeneer, I. Radu and D. Turchinovich.

References

[1] S.A. Wolf et al., Science 294.5546 (2001)
[2] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013)
[3] T. Seifert et al., Nature Phot. 10, 483 (2016)

Invited Talk MA 2.6 Mon 11:45 HSZ 01

Current induced switching of an antiferromagnet — Peter Wadley[1], Michal J. Grzybowski[2], Carl Andrews[1], Sonka Reimers[1], Richard P. Campion[1], Vit Novak[3], Francesco Maccherozzi[4], Sarnjeet S. Dhesi[4], •Kevin W. Edmonds[1], Bryan L. Gallagher[1], Jakub Zelezny[3], and Tomas Jungwirth[3] — [1]University of Nottingham, Nottingham, UK — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland — [3]Institute of Physics, Czech Academy of Sciences, Prague — [4]Diamond Light Source, Oxford, UK

The pioneer of the field of antiferromagnetism, Louis Neel, noted in his Nobel lecture that while abundant and interesting from the theoretical viewpoint, antiferromagnets did not seem to have any applications. The alternating directions of magnetic moments and the resulting zero net magnetization make them difficult to detect and manipulate. Remarkably, Neel also pointed out the equivalence of antiferromagnets with ferromagnets in effects that are an even function of the magnetic moment, but an efficient means of controlling the magnetic order has been elusive. Zelezny et al predicted a mechanism, by which an alternating field-like torque can be produced in crystals of specific symmetries [1]. In some materials these torques can coincide with the spin sub-lattices of the AF, and offer the prospect of current induced switching of the spin axis. This talk reports the demonstration of electrical reading and writing of an all-AF memory device, and complementary X-PEEM imaging[2]. [1] J. Zelezny, et al., Physical Review Letters 113, 157201 (2014). [2] P. Wadley, et al., Science 351, 587-590 (2016)

MA 3: Magnetic Textures: Statics and experimental imaging

Time: Monday 9:30–12:45 Location: HSZ 101

MA 3.1 Mon 9:30 HSZ 101

Topological orbital moments — what they are and where to find them — •Manuel dos Santos Dias, Juba Bouaziz, Mohammed Bouhassoune, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Unconventional magnetic structures, such as skyrmions, host ground state emergent magnetic fields that lead to orbital magnetism, even without the spin-orbit interaction. We have recently explored the properties of these emergent orbital moments [1], starting with first-principles calculations for trimers. Armed with this understanding, we study the orbital magnetism of skyrmions, and demonstrate that the contribution driven by the emergent magnetic field is topological. This means that the topological contribution to the orbital moment does not change under continuous deformations of the magnetic structure. Furthermore, we use it to propose a new experimental protocol for the identification of topological magnetic structures, by soft x-ray spectroscopy.

This work is supported by the HGF-YIG Programme VH-NG-717 (Funsilab) and the ERC Consolidator grant DYNASORE. S.B. acknowledges funding from the European Union's Horizon 2020 grant number 665095 (FET-Open project MAGicSky).

[1] M. dos Santos Dias et al., Nat. Commun. **7**, 13613 (2016)

MA 3.2 Mon 9:45 HSZ 101

General classification of skyrmions among almost all space groups — •Miriam Hinzen[1,2], Stefan Blügel[1], and Christof Melcher[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Mathematics I & JARA FIT, RWTH Aachen University, 52056 Aachen, Germany

In the past years, magnetic B20 compounds have been in the focus of research as prototype materials exhibiting chiral magnetic skyrmions at particular temperatures and magnetic fields. These compounds belong to the space group T. However, there are crystal classes with Dzyaloshinskii-Moriya interaction (DMI) that favour a different two-dimensional magnetic structure, some of which even have a different topological charge. Naturally, the question arises whether there is a possibility to transfer results from one crystal class to another, for example through a transformation formula. We went through all the crystal classes that can form skyrmions and for most of them identified those O(2) symmetry operations relating their magnetization configuration to the one of the B20 compound. Depending on the crystal structure we expect skyrmions or antiskyrmions of vortex, hedgehog or saddle-point type.

MA 3.3 Mon 10:00 HSZ 101

Metastable skyrmionic spin structures with various topologies in an ultrathin film — Levente Rózsa[1], •Krisztián Palotás[2,3], András Deák[2], Eszter Simon[2], Rocio Yanes[4], László Udvardi[2], László Szunyogh[2], and Ulrich Nowak[4] — [1]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [4]University of Konstanz, Konstanz, Germany

Metastable localized spin configurations with topological charges ranging from $Q = -3$ to $Q = 2$ are observed in a $(Pt_{0.95}Ir_{0.05})$/Fe bilayer on Pd(111) surface by performing spin dynamics simulations, using a classical Hamiltonian parametrized by ab initio calculations [1]. It is demonstrated that the frustration of the isotropic exchange interactions is responsible for the creation of these various types of skyrmionic structures. The Dzyaloshinsky-Moriya interaction, present due to the breaking of inversion symmetry at the surface, energetically favors skyrmions with $Q = -1$, distorts the shape of the other skyrmionic objects, and defines a preferred orientation for them with respect to the underlying lattice. By performing spin-polarized scanning tunneling microscopy (SP-STM) calculations, a direct connection between experimentally measurable SP-STM contrasts and different topologies of skyrmionic systems is established [2].

[1] L. Rózsa et al., arXiv:1609.07012 (2016)
[2] K. Palotás et al., arXiv:1609.07016 (2016)

MA 3.4 Mon 10:15 HSZ 101

Antiskyrmions stabilized by anisotropic Dzyaloshinskii-Moriya interaction at interfaces of low symmetry — •Markus Hoffmann[1], Bernd Zimmermann[1], Gideon P. Müller[1], Daniel Schürhoff[1], Nikolai S. Kiselev[1], Christof Melcher[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Mathematics I & JARA FIT, RWTH Aachen University, 52056 Aachen, Germany

While skyrmions – localized and topologically protected vortex-like magnetic textures – are the main focus within the current research field of chiral magnets, we discuss in this contribution the emergence of *antiparticles*, so-called antiskyrmions, magnetic textures with a topological charge opposite to the one of skyrmions. On the level of micromagnetics, we show that chiral magnets cannot only host skyrmions, but also antiskyrmions as least-energy configurations over all non-trivial homotopy classes. We derive practical criteria for their occurrence and coexistence with skyrmions that can be fulfilled by interfaces of low symmetry in dependence of the electronic structure. We propose a whole class of materials as possible candidates for the realization of antiskyrmions, namely ultrathin magnetic films grown on heavy metal substrates with C_{2v} symmetry. An experimentally well-investigated system of this class is the double layer of Fe grown on a W(110) substrate. Combining Density Functional Theory calculations with spin dynamic simulations employing an atomistic-spin model we show that this system hosts stable antiskyrmions rather than skyrmions.

MA 3.5 Mon 10:30 HSZ 101

Observation of topological magnetic defects in helimagnetic FeGe — •Peggy Schönherr[1], Jan Müller[2], Laura Köhler[3], Naoya Kanazawa[4], Manfred Fiebig[1], Yoshi Tokura[4,5], Achim Rosch[2], Markus Garst[3], and Dennis Meier[1,6] — [1]ETH Zürich, Switzerland — [2]Universität zu Köln, Germany — [3]Technische Universität Dresden, Germany — [4]University of Tokyo, Japan — [5]Riken, Japan — [6]Norwegian University of Science and Technology, Norway

Complex spin textures, like helical spin spirals with a fixed wavelength, can occur due to chiral magnetic interactions. Chiral magnets are a striking nanoscopic analog to liquid crystals, possessing lamellar phases and ordered topological defects. Defects are of great importance as they strongly influence order and mobility of the spin system. Here we present the experimental observation of such 1D and 2D objects with non-trivial topology in the helimagnetic phase of FeGe using magnetic force microscopy. We show that the depinning and subsequent motion of edge dislocations govern the local magnetization dynamics. Moreover, the defects can form chains and build topological domain walls, which are distinctly different from classical antiferro- and ferromagnets. Experimentally, three main types of domain walls are found depending on the angle between neighboring domain orientations. The domain walls can also carry a skyrmion charge, which implies a coupling to spin currents and contributions to the topological Hall effect. Thus, going beyond skyrmions, chiral magnets reveal a zoo of magnetic nano-objects with non-trivial topology.

MA 3.6 Mon 10:45 HSZ 101

Direct observation of magnetic surface states in a chiral magnet — •Nikolai S. Kiselev[1], Andras Kovács[2], Filipp N. Rybakov[3], Zi-An Li[2,4], Stefan Blügel[1], and Rafal E. Dunin-Borkowski[2] — [1]Peter Grünberg Institute and Institute for Advanced

Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany — [3]M.N. Miheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Ekaterinburg 620990, Russia — [4]Institute of Physics, Chinese Academy of Sciences, 100190 Beijing, China

We report on the first direct observation of magnetic surface states, which had previously been predicted theoretically, in a chiral magnet [1]. We study the in-field behavior of a thin film of FeGe using Lorentz transmission electron microscopy and off-axis electron holography and infer the projected in-plane component of magnetization in the film from our experimental results using a model-based reconstruction technique. We observe the formation and evolution of surface spin spirals that exhibit hysteretic behavior. In good agreement with theoretical predictions, the observed surface spin spirals show much lower contrast and a much larger modulation period than ordinary helical spin spirals, which appear in lower fields. A comparison of our experimental data with micromagnetic simulations reveals that dipole-dipole interactions play a significant role in the quantitative description of such systems.

[1] F. N. Rybakov et al., New J. Phys. 18, 045002 (2016).

15 min. break.

MA 3.7 Mon 11:15 HSZ 101

Cycloidal and Néel-type skyrmion lattice phases in polar lacunar spinels — •Sándor Bordács[1], Jonathan S White[2], Ádám Butykai[1], Charles D Dewhurst[3], Robert Cubitt[3], Vladimir Tsurkan[4], Alois Loidl[4], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, Budapest, Hungary — [2]Laboratory for Neutron Scattering and Imaging, PSI, Villigen, Switzerland — [3]Institut Laue-Langevin, Grenoble, France — [4]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

Magnetic skyrmions arising from the competition between symmetric and antisymmetric exchange interactions in chiral magnets have attracted much attention due to their potential application in ultra-dense data storage. Recently, we have shown that multiferroic materials - polar magnets - can also host skyrmions. These Néel-type skyrmions have different helicity and they are decorated with non-trivial polarization patterns as well, which may open new ways to manipulate magnetic skyrmions via the electric fields.

In this talk we will report a systematic small angle neutron scattering (SANS) study of polar lacunar spinels, where we observed several phases with modulated magnetic order such as cycloidal and Néel-type skyrmion lattice phases. SANS allowed us to characterize the various phases realized in compounds with easy-axis, easy-plane type magnetic anisotropy as well as lacunar spinels with crystal structures streched and compressed along the polarization.

MA 3.8 Mon 11:30 HSZ 101

Multiscale model for the chiral magnet FeGe — •Sergii Grytsiuk, Markus Hoffmann, Bernd Zimmermann, Gustav Bihlmayer, Nikolai S. Kiselev, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The formation of non-collinear spin textures in noncentrosymmetric cubic B20 materials, such as germanides and silicides, developed into a fascinating topic over the past decade also due to their potential for skyrmion-based memory devices. Further studies of skyrmion properties require precise Heisenberg exchange and Dzyaloshinskii-Moriya interaction parameters entering advanced spin models. We calculate these parameters using density functional theory (DFT), focusing on the FeGe alloy. Among the B20 compounds it has the highest Curie temperature and a helical propagation vector of 70 nm, resulting in a B-field in a skyrmion structure of about the same size. Moreover, spin-fluctuations for FeGe, which are difficult to catch with DFT, are much less important than for e.g. MnSi. We use a multiscale approach combining *ab initio* results, spin dynamics and Monte Carlo simulations to investigate properties of skyrmions in the presence of a magnetic field and electric current. In addition, we extend our studies of chiral magnetism of FeGe from the bulk to thin films where skyrmions are stabilized in a much wider range of temperatures and fields.

Simulations were performed with computing resources granted by JARA-HPC from RWTH Aachen University under project jara0161 and FZJ under projects JIAS1A, IAS-1, and JIFF13.

MA 3.9 Mon 11:45 HSZ 101

Investigation of three-dimensional skyrmion structure of MnGe from first-principles — •Marcel Bornemann, Paul F. Baumeister, Roman Kovacik, Bernd Zimmermann, Phivos Mavropoulos, Samir Lounis, Nikolai S. Kiselev, Peter H. Dederichs, Rudolf Zeller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The magnetic B20 compounds are an interesting class of chiral bulk magnets hosting skyrmions at appropriate temperature and magnetic fields. Among those is MnGe for which experiments [1] indicate a three-dimensional skyrmionic magnetic texture that is currently not understood. In this work we approach the understanding from a full first-principle ansatz based on density-functional theory (DFT). From a methodological point of view such an *ab initio* treatment requests the non-collinear treatment including spin-orbit interactions of easily a few thousand atoms – a challenge, which we can meet with the recently developed Korringa-Kohn-Rostoker Green-function program KKR*nano* [2]. Key to performing such calculations is a linear-scaling behaviour of the code on massively parallel computers with regards to compute time and memory requirements.

Work is supported by the Exascale Innovation Center Jülich. Simulations were performed with computing resources granted by JARA-HPC and Forschungszentrum Jülich.

[1] T. Tanigaki *et al.*, Nano Lett. **15**, 5438 (2015).
[2] A. Thiess *et al.*, Phys. Rev. B **85**, 235103 (2012).

MA 3.10 Mon 12:00 HSZ 101

Isolated skyrmions with vanishing anisotropy in Co/Ru(0001) — •B. Dupé[1], M. Hervé[2], R. Lopez[3], M. Böttcher[1], M. D. Martins[3], T. Balashov[2], L. Gerhard[2], C. Gorenflo[2], J. Sinova[1], and W. Wulfhekel[2] — [1]Johannes Gutenberg Universität, Mainz — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe — [3]Centro de Desenvolvimento da Tecnologia Nuclear, Belo Horizonte, Brazil

Skyrmions are localized and topologically stabilized non-collinear spin structures. Skyrmions offer attractive perspectives for future spintronics applications, because they can be manipulated at lower current densities than domain walls [1]. The stabilization of skyrmions is usually attributed to a large Dzyaloshinskii-Moriya interaction (DMI). DMI is enhanced at surfaces and interfaces via the hybridization of the magnetic atoms with 5d elements [2]. The resulting strong DMI has been able to explain the presence of isolated skyrmions in Co/Pt(111) thin films [3], and [Ir/Co/Pt] superlattices [4]. Here, we show that a strong DMI is not a necessary condition to obtain skyrmions in ultra-thin films. Co/Ru(0001) possesses a spin spiral ground state, although the DMI is weak. We attribute the stability of this spin texture to the simultaneous vanishing of anisotropy. We determine the magnetic interactions in this system using density functional theory and explain the occurrence of isolated skyrmions by Monte-Carlo simulations. [1] A. Fert, et al Nature Nano. 8, 152 (2013). [2] B. Dupé, et al Nature Comm. 7, 11779 (2016). [3] O. Boulle, el al Nature Nano. 11, 449 (2016) [4] C. Moreau-Luchaire, et al Nature Nano. 11, 444 (2016).

MA 3.11 Mon 12:15 HSZ 101

Non collinear magnetism in a Co monolayer probed by spin resolved scanning tunnelling microscopy — •Marie Hervé[1], Bertrand Dupé[2], Rafael Lopez[3], Marie Böttcher[2], Maximiliano D. Martins[3], Timofey Balashov[1], Lukas Gerhard[1], Christian Gorenflo[1], Jairo Sinova[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Institut für Physik, Johannes Gutenberg Universität Mainz, 55128 Mainz, Germany — [3]Centro de Desenvolvimento da Tecnologia Nuclear Serviço de Nanotecnologia Laboratório de Nanoscopia, Belo Horizonte, Brazil

In magnetic thin films the Heinsenberg exchange interaction often leads to a parallel or antiparallel alignment of neighboring spins in the crystal. When inversion symmetry is broken e.g. by a surface or an interface, the non-collinear Dzyaloshinskii-Moriya interaction competes with the Heisenberg exchange interaction. This competition can lead, in some case, to the stabilization of complex spin textures such as spin spirals or skyrmions. We report here on the characterization of a non-collinear magnetic structure in Co(1 ML)/Ru(0001) with spin polarized STM. A chiral spin spiral of 40 nm periodicity in the 1st monolayer as a ground state is evidence. Under magnetic field isolated skyrmions can be stabilized.

MA 3.12 Mon 12:30 HSZ 101

Influence of the surface reconstruction on magnetic interactions in an Fe double-layer on Ir(111) — •M. Dupé[1], S. Heinze[2], and B. Dupé[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz — [2]Institut für Theoretische Physik und Astrophysik, Cristian-Albrechts Universität, Kiel

Skyrmions are localized and topologically stabilized non-collinear spin structures. Isolated skyrmions offer attractive perspectives for future spintronic applications because they can be manipulated at lower current densities than domain walls [1]. Isolated skyrmions have been stabilized and manipulated in the Pd/Fe ultra-thin film on Ir(111) [2]. An effective Hamiltonian parameterized via density functional theory (DFT) has predicted a Curie temperature (Tc) of 100K [3]. Recently, we have shown that Tc could be increased in a multilayer geometry [4]. Here we report on a DFT study of the magnetic interactions of an Fe double-layer on Ir(111) [5]. We determine the magnetic interactions depending on the surface reconstruction and show that the Fe double-layer can be stabilized by the reconstruction from a (111) to a (110) surface. [1] A. Fert, et al Nature Nano. 8, 152 (2013). [2] N. Romming, et al 341, 636 Science (2013). [3] L. Rózsa, et al Phys. Rev. B 93, 024417 (2016). [4] B. Dupé, et al Nature Comm. 7, 11779 (2016). [5] P.-J. Hsu, et al Phys. Rev. Lett. 116, 017201 (2016).

MA 4: Transport: Topological Insulators (jointly with DS, MA, HL, O)

Time: Monday 9:30–13:00 Location: HSZ 204

MA 4.1 Mon 9:30 HSZ 204

Magnetic excitations in the symmetry protected, topological Haldane phase of $SrNi_2V_2O_8$ — Vladimir Gnezdilov[1,2], Vladimir Kurnosov[2], •Peter Lemmens[1], A. K. Bera[3], A. T. M. N. Islam[3], and Bella Lake[3] — [1]TU-BS, Braunschweig — [2]ILTP Kharkov — [3]HZB Berlin

We report results of a single-crystal Raman scattering study of the coupled spin-1 Haldane chain compound $SrNi_2V_2O_8$. In addition to the one-and two-magnon excitations, broad gapless and temperature dependent continua are detected with light polarization parallel to the basal plane. This feature is discussed in terms of spinon-like excitations related to a symmetry protected topological state, of which the Haldane phase in 1D is a preeminent example.

Work supported by RTG-DFG 1952/1, Metrology for Complex Nanosystems and the Laboratory for Emerging Nanometrology, TU Braunschweig.

MA 4.2 Mon 9:45 HSZ 204

Low-temperature magnetotransport in Mn-doped Bi_2Se_3 topological insulators — V. Tkáč[1], V. Komanicky[2], R. Tarasenko[1], M. Vališka[1], V. Holý[1], G. Springholz[3], V. Sechovský[1], and •J. Honolka[4] — [1]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, CZ — [2]Institute of Physics, P. J. Šafárik University, SK — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University, AT — [4]Institute of Physics, Academy of Sciences of the Czech Republic, CZ

Magnetic impurities can break the time-reversal symmetry of 3D topological insulators (TI), thereby opening an energy gap Δ at the Dirac point of a topological surface state with large consequences for transport properties in the thin film limit. In magnetotransport a transition from weak antilocalisation to weak localisation is expected, strongly dependent on contributions from possible coexisting 2D quantum well and bulk states. We present a low-T magnetotransport study ($T = 0.3$ K - 300 K, $B_{\max} = 14$ T) of MBE-grown Bi_2Se_3 films of 20 nm - 500 nm thickness with varying Mn concentrations up to 8% and Curie temperatures $T_C = 5-7$ K [1,2]. The results are interpreted following mainly theory by Lu et al. [3] as a competition of quantum corrections to the conductivity σ (phase coherence length $l_\phi \propto T^{-1/2} \sim 50-150$nm for pure Bi_2Se_3) and 2D e-e interaction corrections both in the ferro- and paramagnetic phase.

[1] M. Valiska et al., Appl. Phys. Lett. 108, 262402 (2016).
[2] R. Tarasenko et al., Physica B 481, 262 (2016).
[3] H.-Z. Lu et al., Phys. Rev. Lett. 112, 146601 (2014).

MA 4.3 Mon 10:00 HSZ 204

Proximity-induced superconductivity and quantum interference in topological crystalline insulator SnTe devices — •Robin Klett[1], Joachim Schönle[2], Denis Dyck[1], Karsten Rott[1], Shekhar Chandra[3], Claudia Felser[3], Wolfgang Wernsdorfer[2], and Günter Reiss[1] — [1]CSMD, Bielefeld University, Germany — [2]CNRS, Institut Neél, France — [3]MPI for Chemical Physics of Solids, Germany

Topological states of matter host a variety of new physics that is promising for future technology. Among these phenomena, the emergence of metallic symmetry-protected topological surface states (TSS) are of major interest. The coupling of topological matter to a nearby superconductor is forsaken to host unconventional proximity-induced superconductivity. We demonstrate the fabrication of superconducting Quantum interference devices (SQUIDs) out of SnTe/Nb hybrid structures. Our findings show strong proximity-induced superconductivity in the surface of SnTe. Transport contributions of Majorana Bound States are predicted to enter with a shift in periodicity to DC SQUID experiments. The Analysis of the SQUID response suggest the absence of periodicity shifts, but show additional features expected for TSS carried supercurrents, such as unconventional Fraunhofer shapes.

MA 4.4 Mon 10:15 HSZ 204

Emergence of topological and topological crystalline phases in $TlBiS_2$ and $TlSbS_2$ — •Udo Schwingenschlögl, Qingyun Zhang, and Yingchun Cheng — King Abdullah University of Science and Technology (KAUST), Physical Science and Engineering Division (PSE), Thuwal 23955-6900, Saudi Arabia

Using first-principles calculations, we investigate the band structure evolution and topological phase transitions in $TlBiS_2$ and $TlSbS_2$ under hydrostatic pressure as well as uniaxial and biaxial strain. The phase transitions are identified by parity analysis and by calculating the surface states. Zero, one, and four Dirac cones are found for the (111) surfaces of both $TlBiS_2$ and $TlSbS_2$ when the pressure grows, which confirms trivial-nontrivial-trivial phase transitions. The Dirac cones at the $\bar{M}$ points are anisotropic with large out-of-plane component. $TlBiS_2$ shows normal, topological, and topological crystalline insulator phases under hydrostatic pressure, thus being the first compound to exhibit a phase transition from a topological to a topological crystalline insulator. [1] Scientific Reports **5**, 8379 (2015)

MA 4.5 Mon 10:30 HSZ 204

Perfect filter for triplet superconductivity on the surface of a 3DTI — •Daniel Breunig[1], Pablo Burset[1], François Crépin[2], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, Wuerzburg University, 97074 Wuerzburg, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, UPMC, Sorbonne Universités, 75252 Paris, France

We study a NSN junction on the surface of a 3D topological insulator (TI), where N is a normal region and S is a s-wave proximity-induced superconducting region. Spin-orbit coupling in the TI breaks spin rotational symmetry and induces unconventional triplet superconductivity.

From the anomalous Green function, we identify the singlet and triplet pairing amplitudes and perform a symmetry classification on these quantities. Pauli exclusion principle demands the antisymmetry of the Green function under simultaneous exchange of its space, time and spin variables. The pairing amplitudes can thus be classified as ESE, OSO, ETO or OTE. Here, the first (last) letter specifies the time/frequency (parity) symmetry (Even or Odd) and the second one describes the spin (Singlet or Triplet). A special feature of our system is the emergence of the exotic odd-frequency pairing.

Interestingly, we find that for a bipolar junction, where the chemical potentials in the N leads only differ in their signs, the non-local singlet pairing amplitude is completely suppressed and only triplet pairing occurs. As a result, the non-local conductance across the junction can be dominated by purely spin triplet crossed Andreev reflections, while electron cotunneling is absent.

MA 4.6 Mon 10:45 HSZ 204

Ferromagnetic transition and fluctuation-induced

Dzyaloshinskii-Morya interaction at the surface of three-dimensional topological insulators — •Flavio Nogueira[1], Ferhat Katmis[2], and Ilya Eremin[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum — [2]Deparment of Physics and Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology

A ferromagnetic insulator (FMI) proximate to the surface of a three-dimensional topological insulator (TI) generate a gap in the spectrum of surface Dirac fermions, provided an out-of-plane exchange exists. We study the ferromagnetic transition in TI-FMI structures and show that fluctuations from Dirac fermions induce a Dzyaloshinskii-Morya (DM) interaction in the effective free energy of the FMI. This DM interaction arises only if the chemical potential is nonzero. Thus, if the proximity effect gaps the Dirac fermions, this means that the Fermi level must be outside the gap in order for a DM term to be induced. We also show that the Curie temperature of the ferromagnetic state at the interface between the TI and FMI is necessarily higher than the bulk Curie temperature of the FMI. This result is corroborated by recent experiments in Bi_2Se_3-EuS bilayer structures. These results imply an interface critical behavior very different from the bulk FMI.

MA 4.7 Mon 11:00 HSZ 204

A time-reversal symmetric topological magnetoelectric effect in 3D topological insulators — •Heinrich-Gregor Zirnstein and Bernd Rosenow — Institut für Theoretische Physik, Universität Leipzig, Germany

One of the hallmarks of time-reversal symmetric (TRS) topological insulators in 3D is the topological magnetoelectric effect (TME). So far, a time-reversal breaking variant of this effect has been discussed, in the sense that the induced electric charge changes sign when the direction of an externally applied magnetic field is reversed. Theoretically, this effect is described by the so-called axion term. Here, we discuss a time-reversal symmetric TME, where the electric charge depends only on the magnitude of the magnetic field but is independent of its sign. We obtain this non-perturbative result by a combination of analytic and numerical arguments, and suggest a mesoscopic setup to demonstrate it experimentally.

In particular, we show that threading a thin magnetic flux tube of one flux quantum through the material and applying a uniform electric field will induce a half-integer charge $\Delta Q = e/2\,\mathrm{sgn}\,\mathbf{E}_z$ on the surface of the topological insulator. The sign of the induced charge is independent of the direction of the magnetic field.

15 min. break.

MA 4.8 Mon 11:30 HSZ 204

Single-electron injection in the edge states of a 2D topological insulator — •Giacomo Dolcetto and Thomas Schmidt — Physics and Materials Science Research Unit, University of Luxembourg

The realization of single-electron sources in integer quantum Hall systems has paved the way for exploring electronic quantum optics experiments in solid-state devices. Recently, two-dimensional topological insulators have also been considered as an interesting playground for implementing electron quantum optics. Here, two electron waveguides emerge at the edge, one for spin-up and one for spin-down electrons. Scattering between the two channels is strongly suppressed and phase-coherent ballistic transport is predicted. In this talk I will characterize the injection of single Kramers pairs from a mesoscopic capacitor: a periodic voltage drive results in the emission of periodic trains of electron and hole Kramers pairs. Due to spin-momentum locking and to the geometry of the device, the injected state is in general a superposition of many different orthogonal states, thus representing an interesting playground not only to study the transport properties, but also to investigate and to measure the entanglement production.

MA 4.9 Mon 11:45 HSZ 204

Odd-frequency superconductivity at the Helical Edge of a 2D Topological Insulator — •Felix Keidel[1], Pablo Burset[1], François Crépin[2], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics and Astrophysics, Würzburg University, 97074 Würzburg, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, UPMC, Sorbonne Universités, 75252 Paris, France

By virtue of the basic laws of quantum mechanics, the Pauli principle demands the Cooper pairs in superconductors to be odd under exchange of the two constituent electrons. Consequently, even-parity singlets are formed in conventional s-wave superconductivity. Exotic unconventional pairing symmetries emerge once the classification is extended to frequency, additionally to orbital and spin degrees of freedom.

In our work, we study a helical edge of a two-dimensional topological insulator in proximity to an s-wave superconductor and ferromagnetic insulators. While helicity and the magnetic field induce triplet correlations in addition to the inherited singlet pairing, both even- and odd-parity contributions arise since translational invariance and inversion symmetry are broken. In such a hybrid junction, odd-frequency amplitudes thus occur naturally as all combinations of spin and parity symmetry appear. On the basis of a Green's function analysis, we find signatures of these unconventional pairing amplitudes in the local density of states and in the non-local conductance. Strikingly, our method allows to track the emergence of unconventional superconductivity and make a connection to transport and pairing properties of the system.

MA 4.10 Mon 12:00 HSZ 204

Parity anomaly driven topological transitions in magnetic field — •Jan Böttcher, Christian Tutschku, and Ewelina M. Hankiewicz — Institut für Theoretische Physik und Astronomie, Uni Würzburg, 97074 Würzburg, Germany

Recent developments in solid state physics give a prospect to observe the parity anomaly in (2+1)D massive Dirac systems. We show, that the charge neutrality condition for a quantum anomalous Hall (QAH) state in orbital magnetic fields gets modified by an additional term originating from an intrinsic Chern-Simons term in the one loop Lagrangian. This can be utilized to experimentally differentiate the QAH from the quantum Hall (QH) state at charge neutrality [1]. As a result, an experimental signature of the QAH phase in magnetic fields is a long $\sigma_{xy} = e^2/h$ ($\sigma_{xy} = -e^2/h$) plateau in $Cr_x(Bi_{1-y}Sb_y)_{2-x}Te_3$ (HgMnTe quantum wells). Furthermore, we predict a new transition between the quantum spin Hall (QSH) and the QAH state in magnetic fields without magnetic impurities but driven by effective g-factors and particle-hole asymmetry.

[1] J. Böttcher, C. Tutschku, E. M. Hankiewicz, arXiv:1607.07768v1

MA 4.11 Mon 12:15 HSZ 204

Tunable edge states and their robustness towards disorder — •Maik Malki and Götz S. Uhrig — Lehrstuhl für Theoretische Physik 1, TU Dortmund, Germany

The interest in the properties of edge states in Chern insulators and in $\mathbb{Z}_2$ topological insulator has increased rapidly in recent years. We present calculations on how to influence the transport properties of chiral and helical edge states by modifications of the edges in the Haldane and in the Kane-Mele model. The Fermi velocity of the chiral edge states becomes direction-dependent as does the spin-dependent Fermi velocity of the helical edge states. Moreover, it is possible to tune the Fermi velocity by orders of magnitude. Additionally, we explicitly investigate the robustness of edge states against local disorder. The edge states can be reconstructed in the Brillouin zone in presence of disorder. The influence of the width and of the length of the system is studied as well as the dependence on the strength of the disorder.

MA 4.12 Mon 12:30 HSZ 204

Instability of interaction-driven topological insulators against disorder — Jing Wang[1,2], Carmine Ortix[1,3], Jeroen van den Brink[1], and •Dmitri Efremov[1] — [1]IFW Dresden, Germany — [2]University of Science and Technology of China, Hefei, China — [3]Utrecht University, Netherlands

We analyze the effect of disorder on the weak-coupling instabilities of quadratic band crossing point (QBCP) in two-dimensional Fermi systems, which, in the clean limit, display interaction-driven topological insulating phases. In the frame of the weak-coupling renormalization group procedure, which treats fermionic interactions and disorder on the same footing, we test all possible instabilities and identify the corresponding ordered phases in the presence of disorder for both single-valley and two-valley QBCP systems. We find that disorder generally has a strong influence on the stability of the interaction-driven topological insulating phases – it strongly suppresses the critical temperature at which the topologically non-trivial order sets in – and can even trigger a phase transition to different, topologically trivial, ordered phases.

MA 4.13 Mon 12:45 HSZ 204

Effect of disordered geometry on transport properties of three dimensional topological insulator nanowires — •Emmanouil Xypakis[1], Jun Won Rhim[1], Roni Ilan[2], and Jens H. Bardarson[1] — [1]Max Planck Institute for the Physics of Complex

Systems, Dresden — [2]Department of Physics, University of California, Berkeley, California

Three dimensional topological insulator nanowires are materials which, while insulating in the bulk, have a metallic boundary described by a two dimensional Dirac Hamiltonian with antiperiodic boundary conditions. Transport properties of this system have been extensively studied in the limit where the surface manifold is conformally at (e.g., a cylinder) in the presence of a random disordered scalar potential. In this talk I will discuss how this picture is altered when a more realistic surface manifold is chosen, such as a cylinder with a randomly fluctuating radius.

MA 5: Magnetization/Demagnetization Dynamics

Time: Monday 9:30–12:15 Location: HSZ 401

MA 5.1 Mon 9:30 HSZ 401

Principle spin-lattice dynamics studies mediated by RKKY and dipole-dipole interaction — •Danny Thonig[1], Jacob Persson[1], Johan Hellsvik[2], Lars Bergqvist[2], Anna Delin[2], Olle Eriksson[1], and Jonas Fransson[1] — [1]Department of Material Theory, Uppsala University, Sweden — [2]Department of Materials and Nano Physics, KTH, 16440 Kista, Sweden

The understanding how magnons couple with phonons is of fundamental importance. It is dominantly caused by distance dependent exchange between the magnetic moment [1], 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 and dipole-dipole 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.

[1] Y. Tokura, S. Seki, and N.Nagaosa, Rep. Prog. Phys. 77, 076501 (2014)

MA 5.2 Mon 9:45 HSZ 401

Modeling of ultrafast magnetization dynamics in synthetic ferrimagnets — •Stefan Gerlach[1], Laszlo Oroszlany[2], Denise Hinzke[1], Steffen Sievering[1], Sönke Wienholdt[1], Laszlo Szunyogh[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budafoki ut 8., HU-1111 Budapest, Hungary

Based on numerical simulations, we demonstrate thermally induced magnetic switching in synthetic ferrimagnets composed of multilayers of rare earths and transition metals. Our findings show that deterministic magnetization reversal occurs above a certain threshold temperature if the ratio of transition metal atoms to rare earth atoms is sufficiently large. Surprisingly, the total thickness of the multilayer system has little effect on switching. We further provide a simple argument to explain the temperature dependence of the reversal process.

MA 5.3 Mon 10:00 HSZ 401

The role of magnetic anisotropy on spin pumping revealed in epitaxial Fe/NM (Pt, Pd, Au) systems — •Sascha Keller, Laura Mihalceanu, Andres Conca, Matthias R. Schweizer, Jochen Greser, Burkard Hillebrands, and Evangelos Th. Papaioannou — Fachbereich Physik, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany

In spintronics, which extends the classical electronics with the spin of electrons as additional degree of freedom, the spin current-to-charge current conversion is an important task for possible interfaces to microelectronic technologies. The spin pumping (SP) and inverse spin Hall effect (ISHE) in bilayers consisting of a ferromagnetic (FM) layer and an attached non-magnetic metal (NM) layer therefore allow for such a conversion. However the role of intrinsic crystalline magnetic anisotropy has not been discussed in the topic of spin pumping, yet. We address this question through bilayers consisting of metallic FM and NM capping layers of high epitaxial quality grown by molecular beam epitaxy (MBE). Due to the use of metallic ferromagnets employing an angular resolved spin pumping measurement setup is crucial to separate spin rectification effects from ISHE. There the external magnetic field is rotated in-plane and the effects can be differentiated due to the different angular dependences of those effects. The epitaxially grown FM/NM interfaces are strongly affecting the spin pumping and rectification effects due to the structural quality of the interface and the intrinsic magnetic anisotropy of the FM. The Carl Zeiss Stiftung is gratefully acknowlegded for financial support.

MA 5.4 Mon 10:15 HSZ 401

Dynamics of coupled topological Solitons — •Fabian Kloodt[1], Robert Frömter[1,2], Philipp Staeck[1], Susanne Kuhrau[1], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

In the framework of the Thiele-equation magnetic vortices and antivortices can be treated as quasi-particles, i.e. solitons. Confining a single (anti-)vortex in a magnetic microstructure causes linear restoring forces, which results in an oscillator equation describing the field-driven motion of individual solitons. Using TR-SEMPA [1] we investigate coupling effects in vortex-antivortex chains in patterned FeCoSiB-structures. While the vortices exhibit a clear oscillation the antivortices show no apparent motion. Both types of magnetic solitons are mutually coupled via the domain energy (part of the stray-field energy), resulting in a coupled oscillation mode under HF-field excitation. TR-SEMPA results and micromagnetic simulations stand in excellent agreement indicating that coupling dominates the motion of the individual solitons.

[1] R. Frömter, Appl. Phys. Lett. 108, 142401 (2016).

MA 5.5 Mon 10:30 HSZ 401

Electron dynamics driving ultrafast magnetization dynamics in itinerant ferromagnets and alloys — •Sebastian Weber and Baerbel Rethfeld — Department of Physics and Research Center Optimas, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale [1].
With help of a spin-resolved Boltzmann description, which allows to describe microscopic collision processes including spin-flips, we have identified the equilibration of chemical potentials of majority and minority electrons as a driving force for ultrafast magnetization dynamics [2].
Recent experiments have revealed element-specific dynamics in exchange coupled ferromagnetic alloys [3]. We set up a microscopic model to trace the electron dynamics with pin-resolution and in dependence on the material in the alloy. We show first results of the interplay between relaxation processes.

[1] E. Beaurepaire et al., PRL 76, 4250 (1996)
[2] B. Y. Mueller et al., PRL 111, 167204 (2013)
[3] S. Mathias et al., PNAS 109, 4792 (2012)

15 min. break.

MA 5.6 Mon 11:00 HSZ 401

Measuring the magnetization dynamic of Fe(110) using a novel high harmonic source. — •Rafael Gort — ETH Zürich, Laboratorium für Festkörperphysik, 8093 Zürich

As ultrafast demagnetization is partially a spin transport effect, the continuously growing field of spintronics is related to femtosecond magnetization dynamics.

Energy resolved photoemission experiments in principle provide the possibility for direct observation of the electrons that contribute to the macroscopic magnetization. However, for a long time the spin detectors have not been efficient enough for spin and time resolved electron spectroscopy of the entire valence band. The development of imaging spin detectors increase the detection efficiency by several orders of magnitude compared to the well-known Mott spin detector.

A spin detector has been developed, where spin selectivity is achieved by low energetic electron scattering at a Iridium crystal. In addition, a very compact and stable high harmonic source has been designed, with the goal of delivering short VUV pulses for just one single center wavelength.

We present first measurements of spin and time resolved photoemission spectra of ultrafast demagnetization in iron. We intend to compare the spin dynamics of electrons at the Fermi energy to the laser-induced change of the exchange splitting. This will lead to deeper insights into transport phenomena within the valence band.

MA 5.7 Mon 11:15 HSZ 401

Ultrafast Lorentz microscopy of nanoscale magnetization dynamics — •Nara Rubiano da Silva[1], Marcel Möller[1], Tim Eggebrecht[2], Jan Gregor Gatzmann[1], Armin Feist[1], Ulrike Martens[3], Henning Ulrichs[2], Markus Münzenberg[3], Claus Ropers[1], and Sascha Schäfer[1] — [1]4th Physical Institute, University of Göttingen, Germany — [2]1st Physical Institute, University of Göttingen, Germany — [3]Interface and Surface Physics, University of Greifswald, Germany

Lorentz microscopy is an established technique for the nanoscale mapping of magnetic structures, exceeding the diffraction-limited resolution of magneto-optical microscopy [1]. However, time-resolved implementations of this method have remained elusive, due to the lack of pulsed electron sources of sufficient brightness and coherence.

Here, we present the implementation of Lorentz microscopy within the ultrafast transmission electron microscope (UTEM) recently developed in Göttingen [2]. We employ highly coherent, sub-ps electron pulses to study laser-induced demagnetization dynamics in permalloy nanostructures. Our approach offers fascinating prospects for elucidating ultrafast spin dynamics and light-induced magnetic textures [3] on the nanoscale.

[1] N. O. Urs *et al.*, AIP Advances **6** (2016).
[2] A. Feist *et al.*, under revision, arXiv:1611.05022 (2016).
[3] T. Eggebrecht *et al.*, under revision, arxiV:1609.04000 (2016).

MA 5.8 Mon 11:30 HSZ 401

Pump-Probe Holographic Imaging of Nanoscale Magnetic Domains — S. Schleitzer[1], L. Müller[1], •M. Riepp[1], A. Philippi-Kobs[1], W. Roseker[1], C. Gutt[1], M. H. Berntsen[1], B. Pfau[2], D. Weder[2], J. Geilhufe[2], C. von Korff Schmising[2], B. Vodungbo[3], J. Gautier[3], K. Li[3], G. Malinowski[3], B. Tudu[3], F. Capotondi[4], E. Pedersoli[4], M. Kiskinova[4], J. Lüning[3], S. Eisebitt[2], and G. Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Université Pierre et Marie Curie, Paris, France — [4]Elettra-Sincrotrone Trieste, Basovizza, Italy

While ultrafast magnetization dynamics of homogeneously magnetized samples has been studied by optical pump-probe techniques since decades, it is still an open question how nanoscale magnetic domain patterns react to an ultrashort optical stimulus. Here, we report on an optical pump–free electron laser (FEL)-probe imaging experiment on a $(Co_{0.4nm}/Pd_{0.2nm})_{30}$ multilayer deposited on a Si_3N_4 membrane. The multilayer exhibits a perpendicular magnetic anisotropy and a disordered maze-domain pattern (domain size of 80 nm). The experiment was conducted at DiProI beamline at FERMI@Elettra using FEL radiation tuned resonantly to the M_3 absorption edge of cobalt. By using Fourier transform holography, the real-space domain configuration could be directly retrieved unambiguously from the scattering data. We fixed the pump-probe delay time to 1 ps and followed the evolution of the domain pattern at different pump fluences revealing ultrafast demagnetization in real space on the nanoscale.

MA 5.9 Mon 11:45 HSZ 401

Quenching of the Resonant Magnetic Scattering Cross Section by Ultra-Short Free-Electron Laser Light Pulses — •L. Müller[1], M.H. Berntsen[2], W. Roseker[1], A. Philippi-Kobs[1], K. Bagschik[3], J. Wagner[3], R. Frömter[3], F. Capotondi[4], E. Pedersoli[4], M.B. Danailov[4], M. Kiskinova[4], H.P. Oepen[3], and G. Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, FS-CXS, Hamburg, Germany — [2]KTH Royal Institute of Technology, Stockholm, Sweden — [3]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Hamburg, Germany — [4]Elettra Sincrotrone Trieste, Basovizza, Italy

The new free-electron laser (FEL) sources provide radiation with unprecedented parameters in terms of ultrashort pulse length, high photon flux, and coherence. These properties make FELs ideal tools for studying ultrafast dynamics in matter on a previously inaccessible level. Yet, FELs do not only probe matter, but can also drive it into highly excited states which are otherwise inaccessible. For example, a state can be reached in which resonant magnetic scattering is highly suppressed [1].

Here, we report on a resonant magnetic scattering experiment, where the focussed FEL light pulses probe the magnetic domain system of a Co/Pt multilayer thin film with perpendicular magnetic anisotropy. Both, single and double FEL pulses at different fluences are used to follow the quenching of the resonant scattering efficiency.

[1] L. Müller et al., Phys. Rev. Lett. **110**, 234801 (2013).

MA 5.10 Mon 12:00 HSZ 401

Imaging of the dynamic magnetoelastic effect in ferromagnetic layers induced by surface acoustic waves — Michael Foerster[1], Ferran Macià[2,3], Nahuel Statuto[3], Simone Finizio[4,5], •Alberto Hernández-Mínguez[6], Sergi Lendínez[3], Paulo Santos[6], Josep Fontcuberta[2], Joan Manel Hernàndez[3], Mathias Kläui[4], and Lucia Aballe[1] — [1]ALBA Synchrotron Light Source, Spain — [2]Institut de Ciència de Materials de Barcelona, Spain — [3]University of Barcelona, Spain — [4]Johannes Gutenberg Universität Mainz, Germany — [5]Paul Scherrer Institut, Switzerland — [6]Paul-Drude-Institut für Festkörperelektronik, Germany

The exploitation of magnetoelasticity is a promising alternative to the use of magnetic fields for the dynamic control of magnetization states of nanoelements. In this contribution, we study the effect of surface acoustic waves (SAWs) on the magnetization dynamics of 20 nm thick nickel nanostructures deposited on a piezoelectric substrate. By combining X-ray magnetic circular dichroism with photoemission electron microscopy, and synchronizing the SAW frequency with the X-rays repetition rate, we obtain simultaneous stroboscopic images of the magnetization domains and the SAW propagating along the nanostructures with temporal resolution down to the picosecond scale. Our results demonstrate a time delay between the magnetization dynamics and the SAW-induced strain field that depends on the orientation of the magnetic domains with respect to the SAW propagation direction. The versatility of our experimental technique provides a new pathway to the quantitative study of dynamic magnetoelastic effects at the nanoscale.

MA 6: Magnetic Instrumentation and Characterization

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

MA 6.1 Mon 9:30 HSZ 403

What is the longitudinal magneto-optical Kerr effect? — Jon Ander Arregi, Patricia Riego, and •Andreas Berger — CIC nanoGUNE, San Sebastian (Spain)

We explore the commonly used classification scheme for the magneto-optical Kerr effect (MOKE), which essentially utilizes a dual definition based simultaneously on: (i) the components of the magnetization vector with respect to the plane of incidence and (ii) specific elements of the reflection matrix, which describe light reflection from a ferromagnetic surface. We find that an unambiguous correspondence in between both definitions is valid only in special cases, while in more general cases, it leads to inconsistencies due to an intermixing of the presumed separate MOKE effects of longitudinal, transverse and polar magnetization components. As an example, we investigate in this work both theoretically and experimentally a material that possesses anisotropic magneto-optical properties in accordance with its crystal symmetry. The derived equations predict a so-far unknown polarization effect for the transverse magnetization component and at the same time, explain inconsistencies in between Kerr rotation and ellipticity measurements in the longitudinal geometry. Experimental results on epitaxial hcp Co films confirm our findings and demonstrate that magneto-optical anisotropy causes significant deviations from the commonly employed MOKE data interpretation scheme.

MA 6.2 Mon 9:45 HSZ 403

Investigation of the domain sizes in Co/Pd multilayers via soft x-ray resonant magnetic scattering — Kai Bagschik[1,2], •Ralph Buss[1,2], Robert Frömter[1,2], Judith Bach[1], Björn Beyersdorff[1], Leonard Müller[3], Stefan Schleitzer[3], Magnus Hårdensson Berntsen[3,4], Christian Weier[5], Roman Adam[5], Jens Viefhaus[3], Claus Michael Schneider[5], Gerhard Grübel[2,3], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]DESY, Hamburg, Germany — [4]KTH Royal Institute of Technology, Kista, Sweden — [5]Peter Grünberg Institut, Jülich, Germany

We present results of a magnetic SAXS experiment on a wedge-shaped $(Co_{0-10\text{Å}}/Pd_{10\text{Å}})_8$ multilayer film in the multidomain state. The diffraction patterns show isotropic rings which result from strongly disordered magnetic domain patterns. To describe the scattering pattern, a model has been developed based on a one-dimensional domain pattern with gamma-distributed domain sizes [1].

Structure factors generated from the model are fitted to the experimental data with very good agreement. The analysis reveals average domain sizes (depending on Co-thickness) that significantly deviate from the value commonly extracted from the peak position of the structure factor. The structure factor is described by the same shape parameter of the gamma distribution independent on the mean domain size.

[1] K. Bagschik, et al., Phys. Rev. B **94**, 134413 (2016).

MA 6.3 Mon 10:00 HSZ 403

Nuclear Magnetic Resonance Force Microscopy at milliKelvin Temperatures — •Gesa Welker, Martin de Wit, Jelmer Wagenaar, Marc de Voogd, Arthur den Haan, Tom van der Reep, Lucia Bossoni, and Tjerk Oosterkamp — Leiden Institute of Physics, Leiden, The Netherlands

Magnetic Resonance Force Microscopy combines Atomic Force Microscopy with Nuclear Magnetic Resonance and aims to obtain a 3D-image with nm-resolution. In the last decade, progress has been made in improving the resolution of this technique, enabling this technique to image a Tobacco Virus with 5 nm resolution [1]. In conventional setups, a laser is used as detection method, giving significant heating of the resonator at temperatures below 1 Kelvin. Our MRFM makes use of superconducting NbTiN detector chips in combination with a Superconducting Quantum Interference Device (SQUID), to generate the necessary RF magnetic fields and to detect the motion of the force sensor. These modifications have allowed us to operate our MRFM at temperatures as low as 20 mK [2], improving the sensitivity towards single spin and opening possibilities to use this technique for interesting condensed matter systems, such as topological insulators, iron-doped palladium, and nitrogen-vacancy centers in diamond.

[1] C. L. Degen et al., Proc. Natl. Acad. Sci. U. S. A. 106, 1313 (2009).
[2] J. J. T. Wagenaar et al., Phys. Rev. Applied 6, 014007 (2016).

MA 6.4 Mon 10:15 HSZ 403

User-selected electron vortex beams for atomic scale magnetic measurements — •Darius Pohl[1], Sebastian Schneider[1,2], Paul Zeiger[3], Jakob Spiegelberg[3], Jan Rusz[3], Peter Tiemeijer[4], Sorin Lazar[4], Xiaoyan Zhong[5], Kornelius Nielsch[1,2], and Bernd Rellinghaus[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, D-01062 Dresden, Germany — [3]Uppsala University, Department of Physics and Astronomy, SE-752 37 Uppsala, Sweden — [4]FEI Company, PO Box 80066, 5600 KA Eindhoven, The Netherlands — [5]NCEM Beijing, Tsinghua University, Beijing 100084, P.R. China

Electron vortex beams (EVBs) carry a discrete orbital angular momentum (OAM), L, and are predicted to reveal magnetic dichroism in electron energy loss spectroscopy upon interacting with magnetic samples. Focusing the probe down to sub-nanometer diameters is, however, a necessary condition to be fulfilled. The generation of atom-size EVBs in the double aberration-corrected FEI Titan^{3}3 80-300 transmission electron microscope (TEM) is achieved by the implementation of a dislocation-type apertures into the condenser lens system. A new optical setup allows for scanning TEM investigations (STEM) with vortex beams, whose OAM is selected by means of an additional discriminator aperture. Performance of this new optical setup is shown by atomic resolution imaging as well as spectroscopy on $SrTiO_3$. First measurements on magnetic samples will be presented.

MA 6.5 Mon 10:30 HSZ 403

Spectroscopy of the quadratic magnetooptic tensor of materials with the cubic structure — •Robin Silber[1,2], Ondřej Stejskal[1], Jan Dušek[3], Lukáš Beran[3], Jaromír Pištora[1], Günter Reiss[2], Martin Veis[3], Timo Kuschel[2,4], and Jaroslav Hamrle[3] — [1]VSB - Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University, Prague, Czech Republic — [4]University of Groningen, The Netherlands

The magnetooptic Kerr effect (MOKE) is a well known and very useful tool in the field of ferromagnetic material characterization [1]. Most of the MOKE techniques rely solely on effects linear in magnetization (**M**). Nevertheless, there is also its part being even in **M**, the quadratic MOKE (QMOKE). Handling and understanding the underlying origin of QMOKE could be key to utilize this method for research of antiferromagnetic materials in the future. Here, we present a technique of QMOKE spectroscopy based on the 8-directional method [2] applied on the Fe thin films grown on MgO substrate. From measured QMOKE spectra, further two complex spectra of quadratic magnetooptic (MO) tensor [3] are yielded, using standard Yeh's 4×4 matrix formalism. Those quadratic MO parameters are further discussed and compared with ab-initio calculations.

[1] T. Kuschel et al., J. Phys. D: Appl. Phys. 44, 265003 (2011)
[2] K. Postava et al., J. Appl. Phys. 91, 7293 (2002)
[3] Š. Višňovský, Czech. J. Phys. B 36, 1424 (1986)

MA 6.6 Mon 10:45 HSZ 403

XAS and XMCD of size-selected lanthanoid clusters and complexes in the gas phase — •Martin Timm[1], Christine Bülow[1], Rebecka Lindblad[1,2], Vicente Zamudio-Bayer[1,3], Bernd von Issendorff[3], and Tobias Lau[1] — [1]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [2]Synkrotronljusfysik, Lunds Universitet, Box 118, 22100 Lund, Sweden — [3]Fakultät für Physik, Universität Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg, Germany

Lanthanoid-based materials are currently of great interest in molecular magnetism because of their unquenched $4f$ orbital magnetic moments. Our cryogenic ion-trap end station at BESSY II allows us to perform x-ray absorption and x-ray magnetic circular dichroism spectroscopy of cold, size-selected, free cluster and organometallic complex ions in the presence of a magnetic field, and to investigate the effect of complexation by ligands on their magnetic properties. We will outline this unique approach to magnetic properties of molecular materials and present first spectroscopic data of free gadolinium and terbium cluster ions and complexes.

MA 6.7 Mon 11:00 HSZ 403

Combining time-resolved Electron Microscopy with in-situ radio-frequency excitation — •Marcel Möller, Nara Rubiano da Silva, Armin Feist, Sascha Schäfer, and Claus Ropers — 4th Physical Institute, Georg-August-University, Göttingen, Germany

Ultrafast Transmission Electron Microscopy (UTEM) is an emerging technique providing simultaneous nanometer spatial and femtosecond temporal resolution. Typically, the structural or electronic processes studied in this approach are triggered by intense optical excitation.

Here, we present our implementation of radio-frequency electrical stimulation in UTEM, synchronized to the train of electron probe pulses. In a first experiment, we quantitatively map the amplitude and phase of localized electrical field distributions at the end of electrical waveguides by the spatial streaking of femtosecond electron pulses. Secondly, we probe the resonant excitation of magnetic vortices by spin-polarized radio-frequency currents using Lorentz-Microscopy with continuous and synchronously-pulsed electron beams. Our work will allow for the time-resolved investigation of numerous resonant and non-resonant phenomena driven in nanostructures with megahertz to terahertz fields and currents.

MA 6.8 Mon 11:15 HSZ 403

High sensitivity quantum limited electron spin resonance spectroscopy — •Sebastian Probst[1], Philippe Campagne-Ibarcq[1], Audrey Bienfait[1], Jarryd J. Pla[2], Denis Vion[1], Daniel Esteve[1], Klaus Moelmer[3], John J. L. Morton[4], and Patrice Bertet[1] — [1]Quantronics group, CEA Saclay, France — [2]School of Electrical Engineering and Telecommunications, University of New South Wales, Australia — [3]Department of Physics and Astronomy, Aarhus University, Denmark — [4]London Centre for Nanotechnology, University College London, United Kingdom

Electron spin resonance (ESR) spectroscopy is widely employed for the detection and characterization of paramagnetic species and their magnetic and chemical environment. In a classical ESR spectrometer, the spins precess in an external magnetic field and emit small microwave signals into a cavity, which are amplified and measured. In this work, we make use of the toolbox of circuit quantum electrodynamics to boost the sensitivity of such a spectrometer by many orders of magnitude to the level of 10^2 spins/$\sqrt{\mathrm{Hz}}$ with a signal-to-noise ratio of 1. This is achieved by using a low impedance, high quality factor superconducting micro-resonator in conjunction with a Josephson parametric amplifier operated below 20 mK. The energy relaxation time T_1 of the spins (Bi donors in ^{28}Si) is limited by the Purcell effect to 21 ms allowing fast repetitive measurements while the coherence time T_2 is approximately 1.7 ms. This work is a step towards inductive detection of individual spins, which would be beneficial for quantum information processing and chemical analysis of materials at the single spin level.

MA 6.9 Mon 11:30 HSZ 403

An element-selective probe of atomic polarization reminiscent of the linear Stark-effect — •Katharina Ollefs[1,3], Verena Ney[2], Fabrice Wilhelm[3], Andrei Rogalev[3], and Andreas Ney[2] — [1]Universität Duisburg-Essen and CENIDE, Germany — [2]Johannes Kepler Universität, Austria — [3]European Synchrotron Radiation Facility (ESRF), France

We have studied Co doped ZnO and range of other polar and non-polar materials using x-ray absorption near-edge spec-troscopy (XANES) in external electric fields [1]. A rigid band shift by a few meV/kV is found which scales linear with the applied field thus being reminiscent of the linear Stark-effect. This is corroborated by the consistent presence of this effect in polar thin films and bulk crystals and its absencein nonpolar materials as well as in conducting films. The observed rigid band shift is isotropic andscales linear with the atomic number of the studied element. Therefore, XANES in electrical fields opens the perspective to study atomic polarization with element specificity in a range of functional materials.

[1] V. Ney, F. Wilhelm, K. Ollefs, A. Rogalev, and A. Ney, Phys. Rev. B 93, 035136 (2016)

MA 7: Analytical Electron Microscopy: SEM and TEM-based Material Analysis

Time: Monday 10:00–13:00 Location: MER 02

Invited Talk MA 7.1 Mon 10:00 MER 02

Point-group sensitive interpretation of EBSD patterns, and the impact of channeling-in and channeling-out of electrons — •Gert Nolze[1] and Aimo Winkelmann[2] — [1]Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin, Germany — [2]Bruker Nano GmbH, Am Studio 2D, 12489 Berlin, Germany

Recent studies contradict the common belief that electron backscatter diffraction follows Friedel's rule. The presentation will demonstrate that entire orientation maps collected under standard acquisition conditions can be processed by pattern matching of experimental with simulated patterns which enables to distinguish between (hkl) and $(\bar{h}\bar{k}\bar{l})$. However, the polarity determination for phases such as GaAs is very difficult since Ga an As have a similar contribution to the backscattered intensity of hkl and $\bar{h}\bar{k}\bar{l}$. We will show that in such case the energy-dispersive X-ray signal can be used, but presently for single orientations only.

It is also frequent practice that an EBSD pattern is mainly reduced to its backscattered diffraction part. This also called *channeling-out* signal is used for the orientation interpretation, phase interpretation etc. The presentation will prove that the *channeling-in* of the electron beam reacts clearly more sensitive regarding orientation variations and is responsible for the orientation contrast in images e.g. collected by a backscattered electron detector. Despite the fascinating misorientation sensitivity a quantitative evaluation seems to be very unlikely.

MA 7.2 Mon 10:30 MER 02

The Complicated Information Depth of EBSD — •Wolfgang Wisniewski — Otto-Schott-Institut, Fraunhoferstr. 6, 07743 Jena, Germany

The information volume of a method enables to estimate which part of a sample actually contributes to the given measurement and establishes boundaries concerning possible measurements. In the case of EBSD, the widespread opinion is that the information depth is limited to 10-40 nm or less. However, recent results show that this information depth depends not only on the material and the available technology, but also on the quality of the pattern being analyzed. In high quality patterns, the evaluated information indeed originates from a very thin layer of material, but the information depth may increase significantly for low quality EBSD-patterns. This aspect e.g. expands the possibilities of EBSD-measurements to materials covered by passivation layers.

MA 7.3 Mon 10:45 MER 02

Quantitative materials characterization at the nanoscale with TKD in SEM — •Laurie Palasse and Daniel Goran — Bruker Nano GmbH, Am Studio 2D, 12489 Berlin, Germany

Characterization of nanostructured materials requires high spatial resolution orientation mapping at large-scale for quantitative results. Because EBSD does not achieve such resolution on bulk samples, these kind of studies are often done using a TEM. However, TEM-based orientation mapping techniques suffer from small field of view. As a result, Transmission Kikuchi Diffraction (TKD) in SEM was developed as a technique capable of delivering the same type of results as EBSD but with a spatial resolution improved by up to one order of magnitude. TKD analysis is conducted on an electron transparent sample using the same hardware and software as for EBSD system. But when using conventional EBSD geometry, the transmitted patterns (TKP) are captured by a vertical phosphor screen with a considerable loss of signal and strong distortions induced by gnomonic projection. The limitations of such sample-detector geometry are overcome by an on-axis detection system. With a horizontal phosphor screen placed underneath the sample, the transmitted signal is captured where it is the strongest and TKPs will have minimal distortions. Using low probe currents, the spatial resolution is increased and the beam-induced specimen drift reduced. The improved stability and high spatial resolution allow the user to conduct large-area TKD orientation mapping, especially when combined with a fast and sensitive EBSD detector.

MA 7.4 Mon 11:00 MER 02

Cryo-EBSD on $BaFe_2As_2$ single crystals — •Aurimas Pukenas[1], Paul Chekhonin[1], Ellen Hieckmann[2], Martin Meissner[2], Saicharan Aswartham[3], Jan Engelmann[3], Bernhard Holzapfel[4], Sabine Wurmehl[3], Bernd Büchner[3], and Werner Skrotzki[1] — [1]Institut für Strukturphysik, Technische Universität Dresden, 01069 Dresden, Germany — [2]Institut für Angewandte Physik, Technische Universität Dresden, 01069 Dresden, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, 01069 Dresden, Germany — [4]Institut für Technische Physik, Karlsruher Institut für Technologie, 76344 Eggenstein-Leopoldshafen, Germany

$BaFe_2As_2$ belongs to the family of iron-based high temperature superconductors. In previous publications it was reported that superconductivity occurs under certain conditions, e.g. by chemical doping, pressure or epitaxial strain. Undoped $BaFe_2As_2$ orders antiferromagnetically at $T_C \approx 140$ K and simultaneously undergoes a tetragonal $I4/mmm$ to orthorhombic Fmmm structural phase transition. The orthorhombic structure leads to the formation of twin lamellae. Investigations reported so far using transmission electron microscopy and polarized light microscopy show inconclusive results with respect to the domain size. To achieve high spatial resolution ($\leq$ 100 nm) an experimental setup was used consisting of a scanning electron microscope with sample holder on a helium cryostat and electron backscatter diffraction (EBSD) technique. EBSD mappings of domains below T_C and after a cooling-warming cycle will be presented and discussed.

15 min. break.

MA 7.5 Mon 11:30 MER 02

Angle-resolved X-ray fluorescence spectroscopy for elemental depth profiling with nanometer resolution — •Ioanna Mnatouvalou, Jonas Baumann, Veronika Swedowski, Malte Spanier, Steffen Staeck, Daniel Grötzsch, Wolfgang Malzer, and Birgit Kanngiesser — Institut für Optik und atomare Physik, Technische Universität Berlin, Deutschland

X-ray fluorescence (XRF) spectroscopy is a well-established analytical tool for the non-destructive investigation of elemental distributions. Typically, the measured fluorescence intensities are converted to elemental concentrations using tabulated atomic cross sections, thus rendering reference-free quantification feasible. With adapted X-ray lenses lateral micro- or even nano-analysis is possible. Depth information, though, is not readily available. Recent development is directed toward angle-resolved (AR) XRF for the derivation of elemental depth profiles with nm resolution. Here, the angle of incidence or emission is varied, thereby changing the fluorescence information depth. The comparison of measured and simulated angular profiles yields information about the stratigraphy of technologically relevant specimen such as multilayer structures, solar cells or transistor gate stacks. We present our lab-based instrumentation in the soft and hard X-ray range. With a flexible spectroscopy chamber and various sources (X-ray tubes, laser-produced plasma source) and detectors (SDD, CCD) AR and especially grazing emission measurements show the feasibility of the analysis independent on large scale facilities such as synchrotron radiation sources.

MA 7.6 Mon 11:45 MER 02

Analysis on nanostructures and samples with high topography using low acceleration voltages — •Max Patzschke — Bruker Nano, Berlin, Germany

Continuing technological advances require the elemental analysis of increasingly smaller structures in many industrial fields, including biological applications, semiconductors, and nanotechnology in general. This confronts the otherwise well proven electron microscope based energy dispersive spectroscopy (EDS) with new challenges. Most of these challenges are due to physical conditions, such as limited resolution and radiation yield in the low energy range requiring the analysis on bulk samples with low accelerating voltages. The necessary of low probe current would give low X-ray count rates with traditional EDX detectors, and only low to intermediate energy X-ray lines with many peak overlaps can be evaluated.

The XFlash FlatQUAD Silicon Drift Detector (SDD) allowing us to overcome these limitations, and offering additional benefits. Using the FlatQuad detector with low accelerating voltages, the element distribution of nanometer-sized structures can be displayed in a short time. Peaks with several overlapping elements (e.g. Co-L, Ni-L, Fe-L) can be deconvolved using the improved atomic database with 250 additional L,M and N lines below 4 keV.

Examples for nanotechnological applications will be presented: mapping of nanoparticles down to 4nm, biological application, samples with high topography and specimen where sample preparation like coating is excluded.

MA 7.7 Mon 12:00 MER 02

Identification of laminates in 10 M martensite Ni-Mn-Ga magnetic shape memory single crystals — •Jaromír Kopeček[1], Ladislav Klimša[1], Ladislav Straka[1], Jan Drahokoupil[1], Petr Veřtát[1], Vít Kopecký[1], Hanuš Seiner[2], Martin Zelený[1], and Oleg Heczko[1] — [1]Institute of Physics of the AS CR, Na Slovance 2, Prague, 182 00, Czech Republic — [2]Institute of Thermomechanics ASCR, Dolejškova 5, 182 00 Prague, Czech Republic

Ni-Mn-Ga is the most studied magnetic shape memory alloy and the most effective example of magnetic shape memory effects. Used single crystals with composition Ni50Mn28Ga22 have monoclinic structure at room temperature, nevertheless the monoclinicity is very weak with respect to both monoclinic angle and lattice parameters a and b. Such structure allows two types of mobile twinning boundaries in magnetic field. The Type I with mirror plane symmetry and more complicated, extremely mobile Type II twinning boundary. Generally, thanks to monoclinicity there exists a hierarchy of twinning on different scales: a-c laminate; monoclinic lamellae - compound twinning; a-b laminate. The complex structure of macrotwinning lamellae and monoclinic twinning was observed many times. However, the third level of lamination, i.e. a-b laminate is hard to observe and describe correctly. We observed whole hierarchy of all three types of laminates by particular SEM observation and manage to identify them using our previous knowledge from optical microscopy, X-ray diffraction and theory of martensite. The identification includes the branching of lamellae on twinning boundaries.

Invited Talk MA 7.8 Mon 12:15 MER 02

Microstructural characterization of non-metallic precipitates in silicon crystallization processes for photovoltaic applications — •Susanne Richter, Martina Werner, Sina Swatek, and Christian Hagendorf — Fraunhofer Center for Silicon Photovoltaics CSP, Otto-Eißfeldt-Str. 12, D-06120 Halle (Saale)

During the directional crystallization of silicon the formation of non-metallic precipitates may occur due to enrichment and segregation of carbon and nitrogen. Different types of precipitates lead to different defects in the later processed solar cells. Extensive material analyses were performed to obtain micro structural, chemical and electrical properties of all occurring precipitate types including analyses via IR microscopy, ToF-SIMS, FIB target preparation for TEM combined with nanospot-EDS and SAED. As a result in addition to the previous state of knowledge a precipitate classification is deduced. Selective material properties are correlated to individual precipitate types such as morphology, crystal structure (and polytype) or the presence of certain impurities. These properties can be used for precipitate identification and prediction of expected defect behavior. Especially the correlation between the found impurities, its concentrations within the precipitates analyzed by ToF-SIMS, EDS and ICP-MS, and the resulting crystallographic microstructure investigated by TEM and SAED are presented in detail.

MA 7.9 Mon 12:45 MER 02

Quantitative high-resolution off-axis electron holography of 2D materials — •Florian Winkler[1,2], Juri Barthel[1,3], Sven Borghardt[4], Amir H. Tavabi[1,2], Emrah Yucelen[5], Beata E. Kardynal[4], and Rafal E. Dunin-Borkowski[1,2] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C), Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Peter Grünberg Institute 5 (PGI-5), Forschungszentrum Jülich, D-52425 Jülich, Germany — [3]Gemeinschaftslabor für Elektronenmikroskopie (GFE), RWTH Aachen University, D-52074 Aachen, Germany — [4]Peter Grünberg Institute 9 (PGI-9), Forschungszentrum Jülich, D-52425 Jülich, Germany — [5]FEI Company, Achtseweg Noord 5, Eindhoven 5600 KA, The Netherlands

Usually, phase information in conventional transmission electron microscopy (TEM) is lost. A fully recorded electron wave function with its amplitude and phase would allow for post-acquisition removal of residual aberrations and thus an accurate quantitative description of a material's atomic structure.

Here, we present electron wave functions reconstructed from high-resolution electron holograms of two-dimensional WSe_2. We show that a very precise knowledge of microscope and sample-related parameters, such as image spread, Debye-Waller factor and specimen tilt, can be obtained by comparing experimental wave functions with simulations. Furthermore, we are able to remove residual aberrations from the experimental data, which enables a quantitative description of the atomic structure, including the detection of structural defects.

MA 8: SKM Dissertation-Prize 2017

Time: Monday 10:30–12:10 Location: HSZ 04

Invited Talk MA 8.1 Mon 10:30 HSZ 04

Coherent Backscattering and Many-Body Spin Echo in Fock Space: Genuine Many-Body Interference vs. Equilibration — •Thomas Engl — Massey University, Auckland, New Zealand

Universal interference effects like coherent backscattering, which manifests itself as an enhancement of the return probability over its classical value in disordered media, play an important role in many different quantum systems. Those effects are accurately described by semiclassical methods in the spirit of Gutzwiller, where quantum coherent effects are characterized by interference between classical paths. In mesoscopic systems semiclassics has proofed to be a very powerful tool to explain and predict such universal interference effects.

We have transferred these methods into the realm of interacting many-body systems enabling us to predict genuine many-body interference effects that lie beyond mean field theories. One is the analog of coherent backscattering in Fock space which is a coherent enhancement of the return probability for many-body states. It implies that quantum interference gives rise to a systematic deviation from full thermalization that is generally assumed to take in for mesoscopic interacting many-body systems. Another example will is many-body spin echo characterized by an increase of the return probability echoing an intermediate sudden spin-flip. It is independent of the interaction strength within a large regime of parameters showing that the well known Hahn (spin) echo cannot be fully destroyed by interactions.

Invited Talk MA 8.2 Mon 10:55 HSZ 04

Magnetization Dynamics of Itinerant and Localized Electrons in Lanthanide Metals — •Björn Frietsch[1,2], Robert Carley[1,2], Martin Teichmann[1,2], Kristian Döbrich[2], John Bowlan[2], and Martin Weinelt[1,2] — [1]Freie Universität Berlin, Berlin, Germany — [2]Max-Born-Institut, Berlin, Germany

Laser induced magnetization dynamics is a very active field of research, not only because of its technological importance but also based on the insights it offers into the fundamental processes that contribute to the transfer of angular momentum from and to the spin system.

To investigate these processes during laser-driven demagnetization we chose the lanthanide metal gadolinium. Using time- and angle-resolved photoelectron spectroscopy we are able to follow the evolution of the exchange-split split valence band-structure which is a measure of the short-range magnetic order of the itinerant 5d6s electrons as well as the magnetization of the localized 4f core level via magnetic linear dichroism. This way we found strikingly different demagnetization time constants of 0.8 ps and 14 ps for the 5d6s and the 4f electrons, respectively. This remarkable difference demonstrates a perturbation even beyond the strong intra-atomic exchange interaction which - thus far - was believed to act on a timescale of a few femtoseconds.

Spin dynamics simulations based on an orbital-resolved Heisenberg Hamiltonian combined with first-principles calculations explain the particular dynamics of 5d6s and 4f spin moments well and suggest that the slow demagnetization of the 4f spin system is almost exclusively driven by phonon-magnon scattering.

Invited Talk MA 8.3 Mon 11:20 HSZ 04

Dynamics of Thin Smectic Films: From Viscous Fluid to Quasi Elastic Behaviour — •Kirsten Harth — Otto von Guericke Universtät Magdeburg

Thin films and their dynamics are involved in numerous physical processes reaching from protein motion in cell membranes to surface coating with thin fluid layers. Smectic liquid crystals are partially ordered fluids, possessing a layered structure, in our case paired with in-plane viscous fluid properties. Free-standing smectic films are stable, they can span areas of several square centimetres at few nanometres thickness. We investigate the relaxation and rupture dynamics of submillimetre to centimetre sized free-floating and sessile smectic bubbles experimentally. An unpreceded crossover from surface tension driven, low-viscosity fluid type relaxation to behaviour reminiscent of vesicles and elastic membranes is observed. A novel model involving multi-fluid flow, and the in-plane and out-of-plane properties of the smectic film is developed to explain the experimental findings.

Invited Talk MA 8.4 Mon 11:45 HSZ 04

Group IV Epitaxy for Advanced Nano- and Optoelectronic Applications — •Stephan Wirths — Peter Grünberg Institut (PGI 9), Forschungszentrum Jülich, 52425 Jülich, Germany — IBM Research - Zurich, 8803 Rüschlikon, Switzerland

The monolithic, large-scale integration of photonics on Si is limited by the inability of Si to emit light efficiently. In this context, Sn-based group IV semiconductors attracted increasing scientific interest during the last decades due to the possibility to pass the indirect-to-direct bandgap transition by alloying Ge with Sn. However, the quality of epitaxially grown GeSn and SiGeSn layers on Si substrates is limited by the low solid solubility of Sn in (Si)Ge ($<$ 1 at.%) and the large lattice mismatch ($>$ 15 %). Here, a low-temperature reduced pressure chemical vapor deposition process was developed for the growth of (Si)GeSn epilayers directly on Si(001) and on Ge-buffered Si(001). High growth rates ($>$ 50 nm/min) at low growth temperatures $< 400°$C are key for Si-Ge-Sn alloys with exceptionally high monocrystalline quality and Sn concentrations far beyond the solid solubility of Sn in (Si)Ge. It was shown that the plastic strain relaxation of these (Si)GeSn epilayers on Ge/Si(001) takes place mostly via edge dislocations rather than via threading dislocations. Furthermore, the indirect-to-direct bandgap transition was presented by means of temperature-dependent photoluminescence measurements. Strain relaxed, direct-gap $Ge_{0.875}Sn_{0.125}$ alloys grown on Si(001) substrates exhibited high modal gain values up to 110 cm^{-1} enabling the first demonstration of lasing action in direct bandgap group IV Fabry-Perot cavities.

MA 9: Novel Functionality and Topology-Driven Phenomena in Ferroics and Correlated Electron Systems (DF with MA, KR, MI, TT and DS)

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

Invited Talk MA 9.1 Mon 15:00 HSZ 02
Ferroelectric domain walls: from conductors to insulators and back again — •Petro Maksymovych — Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, USA

The root cause of uncertainty around conducting ferroelectric domain walls (DWs) is the contact problem, which may be intrinsic to the polarization topology and may not be resolved by doping ferroelectric films. We revealed how contact effects are responsible for apparent DW conductance in ultrathin BiFeO3, wherein the DW electrostatically gates the interface, but is not itself a conductor. At the same time, we explored AC conductance of DWs to eliminate contact effects. DWs in both BiFeO3 and Pb(Zr0.2Ti0.8)O3 revealed robust conductivity at 3 GHz with remarkably large values of 2-6 S/m. Using the Ginzburg-Landau-Devonshire model for ferroelectric semiconductor, the effect is traced to local charge of nominally straight DWs due to defect-induced roughening and/or an intrinsic flexoelectric effect. Microwave regime opens new opportunities for device integration and carrier-density and dielectric effects at DWs.

Support provided by U.S. Department of Energy, BES, Materials Science and Technology Division. Microscopy experiments performed at the Center for Nanophase Materials Sciences, a DOE Office of Science User Facility.

[1] R. K. Vasudevan, et al., and P. Maksymovych, submitted (2016)
[2] A. Tselev, P. Yu, Y. Cao, L. R. Dedon, L. W. Martin, S. V. Kalinin, and P. Maksymovych, Nat. Comms., 7 (2016) 11630.

Invited Talk MA 9.2 Mon 15:30 HSZ 02
Zoology of skyrmions and the role of magnetic anisotropy in the stability of skyrmions — •Istvan Kezsmarki[1], Sandor Bordacs[1], Jonathan White[2], Vladimir Tsurkan[3], Alois Loidl[3], Peter Milde[4], Hiroyuki Nakamura[5], and Andrey Leonov[6] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Paul Scherrer Institute, Villingen, Switzerland — [3]University of Augsburg, Augsburg, Germany — [4]Technical University of Dresden, Dresden, Germany — [5]University of Kyoto, Kyoto, Japan — [6]University of Hiroshima, Hiroshima, Japan

Skyrmions are nanometric magnetic objects with high stability owing to their topological structures. The internal spin pattern of skyrmions depends on the crystal symmetry of the host materials. While we know many chiral crystals hosting Bloch-type skyrmions, Néel-type skyrmions have only recently observed in polar compounds. On experimental basis, I am going to compare the main characteristics of the two types of skyrmions and discuss the effect of magnetic anisotropy on the thermal stability range of the corresponding Bloch- and Néel-type skyrmion lattices.

Invited Talk MA 9.3 Mon 16:00 HSZ 02
Magnetic imaging of topological phenomena in ferroic materials — •Weida Wu — Department of Physics and Astronomy, Rutgers University, Piscataway, NJ, 08854 USA

Topology is a pervasive concept in condensed matter physics. Topological phenomena such as vortices, Skyrmions and chiral edge states are mesoscopic textures that are crucial for the physical properties and functionalities. Thus, it is imperative to directly visualize these mesoscopic phenomena. In this talk, I will present our recent discovery of alternating uncompensated magnetic moments at Z6 vortex domain walls in hexagonal manganites, which demonstrates the coupling between ferroelectric and antiferromagnetic orders. Furthermore, magnetoelectric response of the vortex domains were directly visualized by Magnetoelectric Force Microscopy (MeFM), a combination of MFM with in-situ modulating high electric fields. Our MeFM results reveal a giant enhancement of magnetoelectric response of a lattice mediated magnetoelectric effect near a spin-reorientation critical point.

This work is supported by US DOE under grant DE-SC0008147.

30 min. break

Invited Talk MA 9.4 Mon 17:00 HSZ 02
Topological skyrmion textures in chiral magnets — •Markus Garst — Institut für Theoretische Physik, Technische Universität Dresden, Zellescher Weg 17, 01062 Dresden, Germany

A magnetization that spatially varies within a plane can be characterized by a topological skyrmion number specifying how often the magnetization vector covers the unit sphere. Magnetic skyrmion textures with such a non-trivial winding number are endowed with additional functionality as they efficiently couple to magnon- and itinerant spin currents allowing for novel spintronic applications. Such textures arise, in particular, in chiral magnets where the Dzyaloshinskii-Moriya interaction favours a spatially modulated magnetization. This stabilizes magnetic solitons that carry an integer skyrmion charge as well as regular arrangements thereof, i.e., skyrmion crystals. We demonstrate that defects of helimagnetic order can carry half-integer skyrmion numbers. In analogy to cholesteric liquid crystals, such defects can be interpreted as disclinations and dislocations that are instrumental for the magnetic relaxation process in these systems. We also show that an array of such defects might arise in topological domain walls of helimagnetic order permitting an efficient manipulation by spin currents.

Invited Talk MA 9.5 Mon 17:30 HSZ 02
Learning through ferroelectric domain dynamics in solidstate synapses — Sören Boyn[1], Gwendal Lecerf[2], Stéphane Fusil[1], Sylvain Saïghi[2], Agnès Barthélémy[1], Julie Grollier[1], Vincent Garcia[1], and •Manuel Bibes[1] — [1]Unité Mixte de Physique CNRS/Thales, Palaiseau FRANCE — [2]IMS Laboratory, U. Bordeaux FRANCE

In the brain, learning is achieved through the ability of synapses to reconfigure the strength by which they connect two neurons. Artificial hardware with performances emulating those of biological systems require electronic nanosynapses endowed with such plasticity. Promising solid-state synapses are memristors, simple two-terminal nanodevices that can be finely tuned by voltage pulses. Their conductance evolves according to a learning rule called spike-timing-dependent plasticity, conjectured to underlie unsupervised learning in our brains. We will report on purely electronic ferroelectric synapses and show that spike timing-dependent plasticity can be harnessed and tuned from intrinsically inhomogeneous ferroelectric polarisation switching. Through combined scanning probe imaging and electrical transport experiments, we demonstrate that conductance variations in such BiFeO3-based ferroelectric memristors can be accurately controlled and modelled by the nucleation-dominated electric-feld switching of domains with different polarisations. Our results show that ferroelectric nanosynapses are able to learn in a reliable and predictable way, opening the way towards unsupervised learning in spiking neural networks.

MA 10: Caloric Effects in Ferromagnetic Materials

Time: Monday 15:00–18:30 Location: HSZ 04

Invited Talk MA 10.1 Mon 15:00 HSZ 04

Magnetoelastic coupling and lattice dynamics in magnetocaloric materials — •Markus Ernst Gruner[1], Werner Keune[1], Michael Wolloch[2], Peter Mohn[2], Oliver Gutfleisch[3], Heiko Wende[1], and Rossitza Pentcheva[1] — [1]University of Duisburg-Essen — [2]TU Vienna — [3]TU Darmstadt

Solid state cooling concepts based on magnetocaloric materials offer an energy-efficient alternative to the conventional gas-compressor scheme. Large magnetocaloric effects are observed near magnetic first order transitions which involve a simultaneous change in volume or lattice symmetry and are subject to hysteresis losses. In metamagnetic Heusler alloys, lattice vibrations and magnetic order provide competing contributions to the entropy change, which further reduces the performance [1]. In metamagnetic FeRh [2] and conventional magnetocaloric La-Fe-Si-based compounds [3], lattice and magnetic degrees of freedom contribute cooperatively to the free energy. Comparing recent results from first-principles calculations and nuclear resonant inelastic X-ray scattering, we will review the relevant mechanisms for the favorable coupling of magnetism and lattice degrees of freedom in these two systems and discuss strategies to reduce the intrisic causes of hysteresis.

Contributions from researchers of Argonne National Laboratory, the universities of Bochum, Darmstadt, Duisburg-Essen and Vienna, IFW Dresden, KIT and the SPP 1599 are gratefully acknowledged.

[1] T. Gottschall *et al.*, Phys. Rev. B 93, 184431(2016)
[2] M. Wolloch *et al.*, Phys. Rev. B 94, 174435 (2016)
[3] M. E. Gruner *et al.* Phys. Rev. Lett. 114, 057202 (2015)

MA 10.2 Mon 15:30 HSZ 04

Simulation of complex magnetic intermetallics for ferroic cooling — •Peter Entel and Markus Gruner — Faculty of Physics, University Duisburg-Essen, 47048 Duisburg, Germany

We discuss the structural and magnetic properties of magnetic Heusler intermetallics like Ni-Mn-(Ga, In, Sn) doped with Co, which undergo a magnetostructural phase transition if rapidly quenched. This leads to a large inverse magnetocaloric effect. The coupling of structural and magnetic degrees of freedom is an intrinsic effect and can be explained by a microscopic itinerant band model where electrons are coupled to tetagonal distortions. The model explains why martensitic instability and high-spin state (ferromagnetic order) are mutually exclusive and only distortion and low-spin state (antiferromagnetic order) may coexist. Under magnetic field we observe kinetic arrest phenomena. For the materials which are less rapidly quenched, this magnetostructural phase transition shows time-dependent effects and starts to fade away and phase segregation into cubic ferromagnetic Heusler phase and tetragonal antiferromagnetic Ni-Mn phase occurs for all Mn excess Heusler alloys in agrement with experimental findings [1].

[1] A. Cahir, M. Acet, M. Farle, Sci. Rep. 6, 29831 (2016)

MA 10.3 Mon 15:45 HSZ 04

Substitutional influences on the magnetocaloric properties of the MnNiGe-system — •Andreas Taubel, Tino Gottschall, Konstantin Skokov, and Oliver Gutfleisch — Alarich-Weiss-Straße 16, 64287 Darmstadt

Magnetocaloric materials exhibit a temperature change when placed within a magnetic field under adiabatic conditions. They are studied intensively in order to make it a competitive and more energy efficient cooling technology besides gas compression [1]. The MM'X material system of Mn-Ni-Ge attracts recently significant interest for magnetocalorics because of a sharp and nicely tunable phase transition. The transition temperature can be tuned by Fe substitution for Ni or Mn, which additionally induces ferromagnetic interactions and establishes large magnetization changes.

In our work, the influence of elemental substitutions on the Ge site is studied in detail. The substitution of Si for Ge reduces the amount of expensive Ge and enhances the ferromagnetic behavior leading to a favored transition behavior in low fields. Moreover the mechanical stability of the samples is enhanced compared to brittle MnNiGe, which is important towards utilization of the material for cooling cycles. The high volume change during phase transition is responsible for the initial instability but enables significant pressure tuning, especially for the Si substituted samples. Further substitutions with Al and Sn can be done to completely renounce expensive Ge.

This work was supported by DFG (Grant No. SPP1599).

[1] O. Gutfleisch et al., Adv. Mater. 23, 821-842 (2011)

MA 10.4 Mon 16:00 HSZ 04

Spin dynamics of magnetocaloric compound Mn5Si3 — •Nikolaos Biniskos[1,2], Karin Schmalzl[1], Stephane Raymond[2], Sylvain Petit[3], and Thomas Brueckel[4] — [1]JCNS, Forschungszentrum Juelich GmbH, Outstation at ILL, Grenoble, France — [2]CEA-Grenoble, INAC MEM, 38054 Grenoble, France — [3]CEA-CNRS UMR 12, IRAMIS LLB, 91190 Gif-sur-Yvette, France — [4]JCNS and PGI, JARA-FIT, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany

The magnetocaloric effect (MCE) refers to a change of entropy of a magnetic material exposed to a magnetic field change. A large MCE at room temperature and low magnetic field for a material with abundant and environmentally friendly elements opens the way for magnetic cooling devices. Inelastic neutron scattering (INS) studies might point out ingredients that may favor large MCE. From the Mn5-xFexSi3 series the parent compound Mn5Si3 exhibits positive and negative magnetic entropy change in relation with two distinct antiferromagnetic phase transitions at TN1=66K (AF1: non-collinear, non-coplanar structure) and TN2=99K (AF2: collinear structure), respectively. Experiments performed on a single crystal with unpolarized INS in the paramagnetic (PM) state and in the AF2 and AF1 phases revealed that AF1 is characterized by sharp spin-waves, but AF2 is characterized by a diffuse signal that resembles the one of the PM state, indicating strong spin fluctuations.

MA 10.5 Mon 16:15 HSZ 04

Strain-dependent magnetization measurements of epitaxial Ni-Mn-Ga-Co thin films on piezoelectric substrates — •Benjamin Schleicher[1,2], Stefan Schwabe[1], Robert Niemann[1], Anett Diestel[1], Ruben Hühne[1], Kornelius Nielsch[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, P.O Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, Institute of Solid State Physics, D-01062 Dresden, Germany

Heusler alloys such as Ni-Co-Mn-X (X=Ga, In, Sb, Sn), which show an inverse magnetocaloric effect, are promising materials for solid state cooling. Additionally to high external magnetic fields, the phase transition can also be induced by the application of mechanical stress. This can be realized with an electric field when the magnetocaloric thin film is deposited on a piezoelectric substrate. Thin films are of particular interest since their high surface-to-volume ratio allows fast heat transfer and high cycling frequencies, which leads to higher cooling power using less material. We present an investigation of sputtered epitaxial Ni-Mn-Ga-Co thin films on piezoelectric PMN-PT substrates [1]. Temperature dependent texture and magnetic measurements show the structural and magnetic phase transition in the material. The influence of temperature, magnetic field and mechanical stress on the magnetization of the Ni-Mn-Ga-Co thin film was investigated with a dedicated SQUID setup. In particular, the stress variation was achieved by applying an electric field to the multiferroic stack. This work is supported by DFG through SPP 1599 www.FerroicCooling.de. [1] B. Schleicher et al., J. Appl. Phys. 118 053906 (2015)

MA 10.6 Mon 16:30 HSZ 04

Reversible magnetocaloric effect in Ni-Mn based Heusler alloys — •Parul Devi[1], Mahdiyeh Ghorbani-Zavareh[1,2], Sanjay Singh[1], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden Rossendorf, Dresden, Germany

Magnetic refrigeration technology based on the magnetocaloric effect (MCE) has higher refrigeration efficiency and environment friendly, make it an edge over the others. In comparison to other Magnetocaloric materials, Ni-Mn based Heusler alloys are the subject of special interest as they do not involve toxic and rare earth elements. Heusler alloys show higher value of MCE due to the large magnetization change at their first order magneto-structural transition. Although, Heusler alloys show large MCE, the irreversibility of first order phase transition with respect to the magnetic field cycles is a major issue for practical applications. We show here an enhanced reversibility of MCE in a Ni-Mn-Ga and Ni-Mn-In Heusler alloys. The reversible MCE in these alloys is linked with the volume conversion and geometrical compatibility (co-factor) condition of martensite phase transition.

15 min. break

MA 10.7 Mon 17:00 HSZ 04

Influence of particle orientation on the effective thermal conductivity of magnetocaloric composites — •Kai Sellschopp[1,2,3], Bruno Weise[2,3], Marius Bierdel[2,3], Alexander Funk[2,3], Manfred Bobeth[3], Maria Krautz[2], and Anja Waske[3] — [1]TU Hamburg-Harburg — [2]IFW Dresden — [3]TU Dresden

Plates of epoxy-bonded La-Fe-Si-type particles display improved mechanical stability compared to sintered La-Fe-Si-type plates. The magnetocaloric properties are maintained very well in these composites and they are easy to process. However, the effective thermal conductivity (ETC) is decreased because of the low thermal conductivity of the epoxy. Our idea to overcome this problem without changing the volume fraction of magnetocaloric material is to produce an anisotropic ETC which prefers the out-of-plane direction, thereby enhancing heat transport to the heat exchange fluid. Using the anisotropic shape of the particles this can be achieved by orienting the particles' largest dimension in the out-of-plane direction.

Based on a real 3D data set obtained from X-ray computed tomography (XCT) several particle orientation distributions were modeled using equivalent ellipsoids for the description of particle shape. The ETC tensor was calculated from FEM simulations for all scenarios to study the influence of particle orientation on ETC. The simulations showed that orientation of the particles in the out-of-plane direction can increase the out-of-plane ETC by over 25%.

MA 10.8 Mon 17:15 HSZ 04

Magnetocaloric test bench with a new permanent magnet source — •Dimitri Benke, Jonas Wortmann, Tino Gottschall, Andreas Taubel, Konstantin Skokov, Iliya Radulov, and Oliver Gutfleisch — TU Darmstadt, Funktionale Materialien, Deutschland

Due to the rising demand in energy for cooling applications[1], and the rising problems caused by global warming, it is necessary to find ways to contain it to a bearable level. One possible way is the development of magnetocaloric cooling as an alternative cooling technology with the prospect of being more efficient than regular gas-compression systems [2].

To drive this development, we have built a magnetocaloric testbench that is able to create a siginificant thermal span which allows us to compare different magnetocaloric materials in real-life environments. To improved the testbench, we optimized especially the permanent magnet source. This lead to an increased active volume, higher magnetic field change, lower magnet mass and higher measured thermal span in the testbench.

The dependancy on rare-earths is a problem of magnetocaloric cooling. To show that it is possible to decrease that dependancy, the permanent magnet was manufactured from recycled material in cooperation with Urban Mining Co. This work was supported by the Darmstadt Graduate School of Excellence Energy Science and Engineering.

[1] M. Isaac, D. P. van Vuuren, Energy Policy 37 (2009) 507
[2] C. Zimm et al. (1998) Adv. Cryog. Eng

MA 10.9 Mon 17:30 HSZ 04

Examination of Gd/Gd-Y alloys stacks with different Curie temperatures in a magnetocaloric test bench — •Jonas Wortmann, Dimitri Benke, Tino Gottschall, Marc Pabst, Andreas Taubel, Konstantin Skokov, Iliya Radulov, and Oliver Gutfleisch — TU Darmstadt, Funktionale Materialien, Deutschland

Refrigeration using the magnetocaloric effect has the potential to overtake classical gas compression techniques in regards to efficiency and environmental friendliness [1]. To come closer to the goal of building a working refrigerator a linear magnetocaloric test bench with an average magnetic field change of 1T was built.

This article investigated the options of maximizing the temperature span and lowest achievable temperature by stacking Gd and Gd-Y alloys with different Curie temperatures. The temperatures between the stacks were investigated to estimate the necessary mass of specific of stacks and identify possible efficiency drops inside of the magnetocaloric material. Furthermore, the effect of the frequency, pumped water volume, angle between magnetic field and water flow as well as the utilization of a heat sink were examined.

To evaluate the applicability of the magnetocaloric effect the cooling power and the COP were determined as well as the behavior of the magnetocaloric material when exposed to a heat source were studied.

MA 10.10 Mon 17:45 HSZ 04

Magneto-optical imaging of magnetocaloric particle ensembles — •Anja Waske[1], Alexander Funk[1], Cecilia Bennati[2,3], Francesco Laviano[2], and Rudolf Schäfer[1] — [1]IFW Dresden — [2]Politecnico of Torino — [3]Istituto Materiali Elettronica e Magnetismo del Consiglio Nazionale delle Ricerche, Italy

A combination of 3D structural information obtained by X-ray computed tomography (XCT) with data of 2D methods like magneto-optical imaging or electron backscatter diffraction (EBSD) can expand the scope of these techniques by providing information in the third dimension, like e.g. the size and position of minority phases and defects hidden beneath the observed surface. For magnetocaloric materials, the nucleation and growth of the ferromagnetic phases was observed to strongly depend on such microstructural features [1]. We show that for La(Fe,Co,Si)13, alpha-Fe inclusions and cracks beneath the observed surface can have an impact on the magnetocaloric transition determined at the surface by e.g. magneto-optical imaging. Furthermore, the behavior of magnetocaloric particle ensembles can be tracked down to single particle behavior.

This work is supported by DFG through SPP 1599 Ferroic Cooling and BASF New Business.

1.Bennati, C., et al., JMMM 2016. 400, 339-343.

MA 10.11 Mon 18:00 HSZ 04

Study of magnetic anisotropy in single crystalline Mn1.9Co0.1Sb — •Mamuka Chikovani, Karen Friese, Jörg Voigt, Jörg Persson, and Thomas Brückel — Forschungszentrum Jülich GmbH, JCNS-2/PGI-4

According to the literature, Co-modified compounds in the Mn2Sb system exhibit three different magnetically ordered states [Kanomata at el 1990]. Among them, the transition from the ferrimagnetic to the antiferromagnetic state features a steep M(T) dependence, making it a promising candidate for magnetocaloric applications. We report on the study of the magnetic anisotropy of a single crystal of Mn1.9Co0.1Sb. We synthesized a polycrystalline sample as precursor material for the single crystal in a cold crucible using induction melting procedure, which is followed by the single crystal growth employing the Czochralski method. To check the quality of the samples, we compared x-ray powder diffraction from the precursor material and from a crushed piece of the single crystal, respectively. In addition, we oriented a single crystal by x-ray Laue diffraction to probe the temperature dependent magnetization along the tetragonal c-direction and in a,b-plane using the vibrating sample magnetometer option of a *Quantum Design PPMS. The magnetic response is distinctly different for the directions under study. Along the c-direction, the response is rather antiferromagnetic, while for a field perpendicular to c, the response seems to be ferro/ferri magnetic. Eventually, based on the results, the additional transition can be explained by a powder average of the single crystal response and lead to a new magnetic phase diagram for this compound.

MA 10.12 Mon 18:15 HSZ 04

Vibrational density of states in magnetocaloric, hydrogenated La(FeSi)$_{13}$-based compounds — •Alexandra Terwey[1], Joachim Landers[1], Soma Salamon[1], Werner Keune[1], Valentin Brabänder[2], Oliver Gutfleisch[2], Michael Y. Hu[3], Jiyong Zhao[3], E. Ercan Alp[3], Markus E. Gruner[1], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]TU Darmstadt, Germany — [3]APS, Argonne National Laboratory, USA

By employing ^{57}Fe nuclear resonant inelastic X-ray scattering as in [1], we determined the Fe-projected vibrational density of states (VDOS) of hydrogenated $LaFe_{11.4}Si_{1.6}H_y$ and non-hydrogenated Mn-doped $La_{1.06}Fe_{11.4}Si_{1.5}Mn_{0.1}$ as well as hydrogenated and Mn doped $La_{1.06}Fe_{11.4}Si_{1.5}Mn_{0.1}H_y$. The hydrogenated compounds have potential use as refrigerants due to a first-order magneto-structural phase transition near room temperature. Distinct differences between the VDOS of non-hydrogenated and hydrogenated samples were discovered. This finding is in qualitative agreement with preliminary results from DFT calculations. Vibrational thermodynamic quantities were calculated from the VDOS. The change of vibrational entropy and specific heat across the phase transition was found to be smaller for the hydrogenated than for the non-hydrogenated samples. Our results demonstrate that knowledge of the VDOS is important to understand intrinsic thermodynamics of these magnetocaloric materials. Funding by the DFG (SPP1599) and U.S. DOE (DE-AC02-06CH11357) is acknowledged. [1] M.E. Gruner et al., Phys.Rev.Lett. 114, 057202 (2015)

MA 11: INNOMAG e.V. Dissertationspreis und Diplom-/Masterpreis 2017

Die Arbeitsgemeinschaft Magnetismus der DPG schreibt einen Diplom- bzw. Masterpreis und einen Dissertationspreis aus, welche auf der Frühjahrstagung der DPG im März 2017 in Dresden vergeben werden. Ziel der Preise ist die Anerkennung herausragender Forschung im Rahmen einer Diplom-Masterarbeit beziehungsweise eine Doktorarbeit und deren exzellente Vermittlung in Wort und Schrift. Nominierungsfähig waren wissenschaftlich herausragende Diplom- bzw. Masterarbeiten oder Dissertationen auf dem Fachgebiet Magnetismus in Theorie, Grundlagen und/oder Anwendungen, die im Jahr 2016 an einer deutschen Hochschule abgeschlossen wurden. Der (die) Sieger(in) des Diplom-/Masterpreis hält den ersten Kurzvortrag über seine Arbeit in dieser Sitzung. Für den Dissertationspreis ermittelt das Preiskommittee bis zu vier Finalisten, die in diesem Symposium einen Vortrag mit Diskussion über ihre Arbeit halten. Unmittelbar nach dem Symposium wählt das Preiskomitee den (die) Sieger(in). Das Preisgeld beträgt 500 EUR für den Diplom-/Masterpreis und 1.000 EUR für den Dissertationspreis

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

Presentations of Nominees

MA 12: Transport: Graphene and Carbon Nanostructures (jointly with DY, DS, HL, MA, O)

Time: Monday 15:00–18:15 Location: HSZ 204

MA 12.1 Mon 15:00 HSZ 204

Creating and steering highly directional electron beams in graphene — Ming-Hao Liu[1,2], •Cosimo Gorini[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, Regensburg, Germany — [2]Department of Physics, National Cheng Kung University, Tainan, Taiwan

We put forward a concept to create highly collimated, non-dispersive electron beams in pseudo-relativistic Dirac materials such as graphene or topological insulator surfaces [1]. Combining negative refraction and Klein collimation at a parabolic *pn* junction, the proposed lens generates beams, as narrow as a few Fermi wave lengths, that stay focused over scales of several microns and can be steered by a magnetic field without losing collimation. We demonstrate the lens capabilities by applying it to two paradigmatic settings of graphene electron optics: We propose a setup for observing high-resolution angle-dependent Klein tunneling, and, exploiting the intimate quantum-to-classical correspondence of these focused electron waves, we consider high-fidelity transverse magnetic focusing accompanied by simulations for current mapping through scanning gate microscopy. Our proposal opens up new perspectives for next-generation graphene electron optics experiments.

[1] M.-H. Liu, C. Gorini, K. Richter, arXiv:1608.01730.

MA 12.2 Mon 15:15 HSZ 204

Graphene *p-n* junction in a magnetic field as a valley switch — •Tibor Sekera, Rakesh P. Tiwari, and Christoph Bruder — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Low-energy excitations in graphene exhibit relativistic properties due to the linear dispersion relation close to the Dirac points in the first Brillouin zone. Two of the cones located at opposite corners of the first Brillouin zone can be chosen as inequivalent, representing a new *valley* degree of freedom, in addition to the charge and spin of an electron. Using the valley degree of freedom to encode information aroused significant interest, both theoretically and experimentally, and gave rise to the field of *valleytronics*.

We study a graphene *p-n* junction in an out-of-plane magnetic field as a platform to generate and controllably manipulate the valley polarization of electrons. We show that by tuning the external potential giving rise to the *p-n* junction we can switch the current from one valley polarization to the other. We also consider the effect of different types of edge terminations and present a setup, where we can partition an incoming valley-unpolarized current into two branches of valley-polarized currents. The branching ratio can be chosen by changing the location of the *p-n* junction.

MA 12.3 Mon 15:30 HSZ 204

Probing electronic wave functions in a nanotube quantum dot via conductance in a magnetic field — Magdalena Marganska[1], Alois Dirnaichner[1,2], Daniel R. Schmid[2], Peter L. Stiller[2], Christoph Strunk[2], Milena Grifoni[1], and •Andreas K. Hüttel[2] — [1]Institute for Theoretical Physics, Universität Regensburg, Regensburg, Germany — [2]Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany

The tunneling of electrons through a contact between two systems depends on the overlap of their electronic wave functions. In quantum dots the overlap is often tuned via the height of tunneling barriers. Conversely, in carbon nanotubes the unique combination of cylindrical topology and honeycomb atomic lattice allows for a manipulation of the longitudinal component of the electronic wave function via a parallel magnetic field. The amplitude of the wave function at the point of contact with the leads is directly reflected in the coupling strength. Experimentally, we detect the changes in the electronic wave function through the evolution of conductance resonances corresponding to single particle quantum states with magnetic field. The magnitude of the magnetic field in our experiment, up to 17 T, allows us to confirm our prediction of the very different behaviour of the two valley states. The K' valley states experience a strengthening of the tunnel coupling at low magnetic field, followed by subsequent decoupling. In contrast, the K valley states decouple from the leads monotonically, and coupling becomes unmeasurably small already for moderate magnetic fields.

MA 12.4 Mon 15:45 HSZ 204

Electron-electron interaction correction to tunneling in graphene-graphene nanojunctions — •Matthias Popp, Ferdinand Kisslinger, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, FAU Erlangen-Nürnberg (FAU), Erlangen, Germany.

In weakly disordered conductors, electron-electron interaction is expected to provide a zero-bias anomaly in tunneling characteristics [1]. This purely electronic effect is seemingly suppressed in scanning tunneling spectroscopy experiments on graphene due to momentum mismatch, which requires phonon assisted tunneling. [2,3]. In order to overcome this limitation, we fabricate in-plane graphene-graphene nanojunctions by an electro burning process using epitaxial graphene on SiC as starting material. In some junctions with an overall conductance of about e^2/h we indeed observed a zero-bias anomaly at low temperatures which follows the logarithmic scaling characteristics predicted by *Altshuler* and *Aronov*. These experiments offer the opportunity to study the nonlocal aspects of electron tunneling via manipulation of the environment.

[1] Altshuler, B. L. and Aronov, A. G., *Electron-Electron Interaction in Disordered Conductors*, 1985
[2] Brar, V. W. et al., Applied Physics Letters, 2007, 91, 122102
[3] Zhang, Y. et al., Nature Physics, 2008, 4, 627-630

MA 12.5 Mon 16:00 HSZ 204

Electroluminescence of Graphene Nanojunctions — •Christian Ott, Konrad Ullmann, and Heiko B. Weber — Lehrstuhl für Angewandte Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 7/A3, D-91058 Erlangen, Germany

We report on electroluminescence (EL) detected at graphene nanojunctions, the latter being formed by electroburning of epitaxial graphene ribbons on silicon carbide [1]. The EL shows a broad spectrum with emphasis on the near infrared regime. Its intensity scales with applied current and is temperature independent down to liquid helium temperatures. Surprisingly, we find a weak voltage dependence. The spectrum is similar to blackbody radiation with apparent temperatures well above the damage threshold of graphene and the silicon carbide substrate. A similar phenomenon has already been observed in single atom point contacts [2] and island metal films [3]. There a model was proposed based on hot electron luminescence which goes along with a large mismatch between electron gas temperature and lattice temperature due to a reduced electron-phonon interaction in nanoscopic structures. A critical discussion of the underlying mechanism is provided.

[1] Ullmann et al, Nano Letters 15, 5 (2015)
[2] Downes et al., Applied Physics Letters 81, 7 (2002)
[3] Fedorovich et al., Physics Reports 328 (2000)

MA 12.6 Mon 16:15 HSZ 204

Reversible Photochemical Control of Doping Levels in Supported Graphene — •Marie-Luise Braatz[1,2], Nils Richter[1,2], Hai I. Wang[1], Axel Binder[3], Mischa Bonn[4], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), 55128 Mainz, Germany — [3]BASF SE, 67056 Ludwigshafen, Germany — [4]Max Planck Institute for Polymer Research, 55128 Mainz, Germany

The type and density of carriers in graphene are important parameters to control its properties. Based on Terahertz (THz)-spectroscopy and electrical characterization of Nitrogen-doped graphene, we show that the doping level can be optically tuned between the p-type and intrinsic n-type regime [1]. This is achieved photochemically by controlling the dynamical equilibrium between the oxygen adsorption and desorption process via UV laser pulse irradiation treatment [2]. This approach is reversible, easy to use and contact free. This simple method can be used to write doping structures with spatial control by a focused laser beam, not requiring sophisticated nanostructuring to generate doping for instance by gate electrodes that need to be defined at the time of device fabrication.

[1] H. I. Wang, M.-L. Braatz et al., submitted (2016)
[2] S. M. Hornett et al., Phys Rev B 90 (2014)

15 min. break.

MA 12.7 Mon 16:45 HSZ 204

Time evolution of Floquet states in graphene — •Matteo Puviani[1], Francesco Lenzini[1], and Franca Manghi[1,2] — [1]Dipartimento FIM, Università di Modena e Reggio Emilia — [2]CNR - Institute of NanoSciences - S3, Modena

When a time-periodic field is applied to electrons in a lattice the Bloch theorem can be applied twice, both in space and in time, to describe the photon-dressed quasiparticles which are formed. This is the essence of Floquet theory, which has recently attracted a large renewed interest for its ability to describe topological phases in driven quantum systems. The discovery that circularly polarized light may induce nontrivial topological behavior in materials which would be standard in static condition has opened the way to the realization of the so-called Floquet Topological Insulators. In these systems, the topological phases may be engineered and manipulated by tunable controls such as polarization, periodicity and amplitude of the external perturbation.

In the presence of a continuous time-periodic driving, electrons are in a non-equilibrium steady state characterized by a time-periodic dependence of the wave function, and therefore of the expectation values of any observable. In this talk we will consider the prototypical case of graphene that, under the influence of circularly polarized light, exhibits in its Floquet band structure the distinctive features of a topological insulator, namely a gap in 2D and linear dispersive edge states in 1D (graphene nanoribbon). In particular, we will discuss how these characteristics affect the time behavior of some relevant observables such as energy, charge and current density.

MA 12.8 Mon 17:00 HSZ 204

Quantum chaos and out-of-time order correlation functions in graphene — •Markus Klug, Mathias Scheurer, and Jörg Schmalian — Institute for Theoretical Condensed Matter Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Deutschland

Out-of-time order correlation functions of type $C = \langle A(t)B(0)A(t)B(0)\rangle_\beta$ are believed to be a reasonable measure of quantum chaos which manifests in an exponential growth of C with a certain Lyapunov exponent determined by the microscopic model under considerations. Recently, it was conjectured hat this Lyapunov exponent is be bounded by $\lambda \leq 2\pi k_B T/\hbar$ [1].

In this work we investigate the out-of-time order correlation functions in graphene subject to the long range Coulomb interaction. To this end we develop a formalism to capture the relevant effects which determines the dominant time dependence of C. We demonstrate that the critical Dirac fluid graphene is a good candidate for saturating the bound mentioned above.

[1] J. Maldacena, S.H. Shenker and D. J. Stanford, High Energ. Phys. (2016) 2016: 106.

MA 12.9 Mon 17:15 HSZ 204

Interaction induced Dirac fermions from quadratic band touching in bilayer graphene — •Thomas C. Lang[1], Sumiran Pujari[2], Ganpathy Murthy[2], and Ribhu K. Kaul[2] — [1]Institute for Theoretical Physics, University of Innsbruck, Austria — [2]Department of Physics & Astronomy, University of Kentucky, Lexington, KY

We revisit the effect of local interactions on the quadratic band touching (QBT) of Bernal stacked bilayer graphene models using renormalization group (RG) arguments and quantum Monte Carlo simulations of the Hubbard model. We present an RG argument which predicts, contrary to previous studies, that weak interactions do not flow to strong coupling even if the free dispersion has a QBT. Instead they generate a linear term in the dispersion, which causes the interactions to flow back to weak coupling. Consistent with this RG scenario, in unbiased quantum Monte Carlo simulations of the Hubbard model we find compelling evidence that antiferromagnetism turns on at a finite U/t, despite the $U = 0$ hopping problem having a QBT. The onset of antiferromagnetism takes place at a continuous transition which is consistent with $z = 1$ as expected for Gross-Neveu criticality. We conclude that generically in models of bilayer graphene, even if the free dispersion has a QBT, small local interactions generate a Dirac phase with no symmetry breaking and there is a finite-coupling phase transition out of this phase to a symmetry-broken state.

MA 12.10 Mon 17:30 HSZ 204

Dynamical charge and pseudospin currents in graphene and possible Cooper pair formation — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics (IIP) Av. Odilon Gomes de Lima 1722, 59078-400 Natal, Brazil — Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany

With the quantum kinetic equations for systems with SU(2) structure, regularization-free density and pseudospin currents are calculated in graphene realized as the infinite mass-limit of electrons with quadratic dispersion and a proper spin-orbit coupling. The intraband and interband conductivities are discussed with respect to magnetic fields and magnetic domain puddles. The optical conductivity agrees well with the experimental values using screened impurity scattering and an effective Zeeman field. The universal value of Hall conductivity is shown to be modified due to this Zeeman field. The pseudospin current reveals an anomaly since a quasiparticle part appears though it vanishes for particle currents. The density and pseudospin response functions to an external electric field are calculated and the dielectric function is discussed with respect to collective excitations. A frequency and wave-vector range is identified where the dielectric function changes sign and the repulsive Coulomb potential becomes effectively attractive allowing for Cooper pairing.

[1] Phys. Rev. **B 94** (2016) 165415

MA 12.11 Mon 17:45 HSZ 204

Interplay between the long-range Coulomb interaction and edge-state magnetism in zigzag graphene nanoribbons — •Marcin Raczkowski and Fakher Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Quasi-one-dimensional graphene nanoribbons terminated by zigzag edges host partially flat bands at the Fermi energy. Theoretical studies of the Hubbard model with the effective on-site interaction only predict spontaneously induced spin polarizations at the zigzag edges and the associated finite dispersion of the low-energy band. Here, we revisit the stability and dynamical signatures of spin-polarized edge states by performing projective quantum Monte Carlo simulations of a more realistic model with long-range Coulomb interactions. On the one hand, increasing the relative strength of nonlocal interactions with respect to the on-site repulsion reduces noticeably the spin correlation length along the zigzag edge; nevertheless the tendency towards the extended spin polarization along the edges remains dominant over the competing short-range charge correlations. On the other hand, growing charge fluctuations are responsible for the emergence of incoherent low-energy excitations in the dynamical charge structure factor. In addition, we resolve a systematic shift of the dominant low-energy peak in single-particle spectral function on the edge towards higher frequencies that we attribute to quasiparticle scattering from charge excitations.

MA 12.12 Mon 18:00 HSZ 204

Quantum phase transition in effective spin ladders derived from graphene nanoribbons — •Cornelie Koop and Stefan Wessel — Institut für Theoretische Festkörperphysik, RWTH Aachen University

Zigzag edges of graphene nanoribbons host localized edge states, which show a ferromagnetic coupling along each edge and an antiferromagnetic one to the opposite edge. Using an effective model that treats the edge-bulk interaction as a perturbation to the edge-edge interaction, we can drastically reduce the numerical effort needed for this system, and we eventually find a rather general spin ladder model.

We examine this model at low, but finite temperatures by means of Monte-Carlo techniques using the stochastic series expansion method. Susceptibilities and correlation functions can be investigated. We find a quantum-phase transition (QPT), as a function of the antiferromagnetic inter-leg coupling strength, between a weak-coupling phase with long-range ferromagnetic order along each leg, which does not have a spin excitation gap, and a disordered, gapped singlet-phase. The location and estimates for the critical exponents are assessed by numerical methods and compared to known results from renormalization group calculations.

MA 13: Transport: Topological Phases (jointly with DS, MA, HL, O)

Time: Monday 15:00–18:00 Location: HSZ 304

MA 13.1 Mon 15:00 HSZ 304

Dynamical Buildup of a Quantized Hall Response from Non-Topological States — Ying Hu[1], Peter Zoller[1,2], and •Jan Carl Budich[3] — [1]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria — [2]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [3]Department of Physics, University of Gothenburg, SE 412 96 Gothenburg, Sweden

We consider a two-dimensional system initialized in a topologically trivial state before its Hamiltonian is ramped through a phase transition into a Chern insulator regime. This scenario is motivated by current experiments with ultracold atomic gases aimed at realizing time-dependent dynamics in topological insulators. Our main findings are twofold. First, considering coherent dynamics, the non-equilibrium Hall response is found to approach a topologically quantized time averaged value in the limit of slow but non-adiabatic parameter ramps, even though the Chern number of the state remains trivial. Second, adding dephasing, the destruction of quantum coherence is found to stabilize this Hall response, while the Chern number generically becomes undefined. We provide a geometric picture of this phenomenology in terms of the time-dependent Berry curvature.

MA 13.2 Mon 15:15 HSZ 304

Sign reversal of the quantized topological Hall effect in skyrmion crystals — •Börge Göbel[1], Alexander Mook[1], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

The topological Hall effect (THE) of electrons [1] is the hallmark of a skyrmion crystal phase [2]. It can be understood either by coupling of the electrons' spin to the local magnetic texture (Zeeman interaction) or by coupling of the electrons' charge to the emergent field generated by the texture (Peierls substitution).

Here, we study the THE on a triangular lattice, addressing band structure, Hall conductivity, and topological surface states. In this system, the THE is quantized and the transverse conductivity changes sign if the Fermi energy crosses a van Hove singularity. By mapping the THE to a quantum Hall effect (QHE) on a lattice [3], we assign this prominent feature to the cyclotron mass of electron orbits, that is, when constant-energy cuts of the band structure change from electron to hole pockets. Based on this picture, we derive an approximate rule which allows to determine the energy dependence of the topological Hall conductivity in *any* two-dimensional lattice.

[1] K. Hamamoto et al., Phys. Rev. B **92**, 115417 (2015)
[2] S. Mühlbauer et al., Science **323**, 915 (2009)
[3] Y. Hatsugai et al., Phys. Rev. B **74**, 205414 (2006)

MA 13.3 Mon 15:30 HSZ 304

Edge states and topology in finite-length single-wall carbon nanotubes — •Wataru Izumida[1,2], Rin Okuyama[3], Ai Yamakage[4,5], Mikio Eto[3], and Riichiro Saito[1] — [1]Department of Physics, Tohoku University, Sendai 980-8578, Japan — [2]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Faculty of Science and Technology, Keio University, Yokohama 223-8522, Japan — [4]Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan — [5]Institute for Advanced Research, Nagoya University, Nagoya 464-8601, Japan

Edge states in finite-length single-wall carbon nanotubes, which appear in the energy gap of the bulk states, are studied from the topological viewpoint [1,2]. An effective one-dimensional (1D) lattice model is introduced to analyze the quantum system with boundary. By analyzing the 1D lattice model, a bulk-edge correspondence, relationship between the number of edge states in the energy gap and the topological winding number defined in the corresponding bulk system, is given [1]. Manipulation of the edge states by magnetic field [3,4] is suggested in terms of the topological phase transition [2].

[1] W. Izumida, R. Okuyama, A. Yamakage, R. Saito, Phys. Rev. B 93, 195442 (2016).
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[3] K. Sasaki, S. Murakami, R. Saito, Y. Kawazoe, Phys. Rev. B 71, 195401 (2005).
[4] M. Marganska, M. del Valle, S. H. Jhang, C. Strunk, M. Grifoni, Phys. Rev. B 83, 193407 (2011).

MA 13.4 Mon 15:45 HSZ 304

Topological invariants in carbon nanotubes with superconducting pairing — •Lars Milz[1], Magdalena Marganska[1], Wataru Izumida[1,2], and Milena Grifoni[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93 047 Regensburg, Germany — [2]Department of Physics, Tohoku University, Sendai 980-8578, Japan

The symmetries present in a gapped Hamiltonian system determine the types of topological invariants which can be defined for that system. Our case of interest here is a carbon nanotube, which in its normal state is known to possess a non-trivial integer topological invariant, the winding number. Its value determines the number of edge states. When a superconducting pairing is imposed on the nanotube, the symmetry class of the system changes and it is possible to define also a Z2 Pfaffian topological invariant, exploiting the particle-hole rather than the chiral symmetry. We explore the relationship between the two invariants and their influence on the energy spectrum and eigenstates, in particular the edge modes, of a finite carbon nanotube.

MA 13.5 Mon 16:00 HSZ 304

Renormalization group approach to topological phase transitions — •Wei Chen[1], Manfred Sigrist[1], and Andreas Schnyder[2] — [1]ETH Zurich, Zurich, Switzerland — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Have you thought about this: every time you tie your shoelaces, you are using a scaling procedure (the tying) to make the topology (the knot) more obvious? Akin to knot-tying, a renormalization group approach is proposed to judge topological phase transitions for systems that belong to any dimension and symmetry class, and whether the topological phase transition is driven by noninteracting parameters (hopping, chemical potential, etc) as in the usual topological insulators, or interacting parameters (Hubbard interaction, etc) as in fractional Chern insulators. The meaning of scale invariance at the critical point and the fixed point is shown to be related to the notion of correlation length, which was previously thought to be nonexistent for topological insulators.

[1] W. Chen, J. Phys. Condens. Matter 28, 055601 (2016)
[2] W. Chen, M. Sigrist, and A. P. Schnyder, J. Phys. Condens. Matter 28, 365501 (2016)

MA 13.6 Mon 16:15 HSZ 304

Fermionic topological quantum states as tensor networks — •Carolin Wille, Oliver Buerschaper, and Jens Eisert — Institut für theoretische Physik, Freie Universität Berlin

Tensor network states, and in particular projected entangled pair states, play an important role in the description of strongly correlated quantum lattice systems. They do not only serve as variational states in numerical simulation methods, but also provide a framework for classifying phases of quantum matter and capture notions of topological order in a stringent and rigorous language. The rapid development in this field for spin models and bosonic systems has not yet been mirrored by an analogous development for fermionic models. In this work, we introduce a tensor network formalism capable of capturing notions of topological order for quantum systems with fermionic components. At the heart of the formalism are axioms of fermionic matrix product operator injectivity, stable under concatenation. Building upon that, we formulate a Grassmann number tensor network ansatz for the ground state of fermionic twisted quantum double models. A specific focus is put on the paradigmatic example of the fermionic toric code. This work shows that the program of describing topologically ordered systems using tensor networks carries over to fermionic models.

15 min. break.

MA 13.7 Mon 16:45 HSZ 304

Finite-size scaling around a topological phase transition — •Tobias Gulden[1,2], Yuting Wang[2], and Alex Kamenev[2] — [1]Technion - Israel Institute of Technology — [2]University of Minnesota

The critical point of a phase transition is described by a conformal field theory, where perturbations away from criticality are known to give rise to universal scaling functions. We consider perturbations around a critical point which separates two distinct topological phases. For both energy and entropy we find the existence of scaling functions which depend on the sign of the perturbation, i.e. they discriminate between topological phases. Renyi entropy of the Kitaev model contains two distinct scaling functions which separate a well-known universal part and the topological contribution, while energy has one asymmetric scaling function. The latter is universal for all five Altland-Zirnbauer symmetry classes with non-trivial topology in one spatial dimension.

MA 13.8 Mon 17:00 HSZ 304

Fractionalization of charge and energy after electron injection in 1D helical systems — •Alessio Calzona[1,2,3], Matteo Acciai[1], Matteo Carrega[4], Fabio Cavaliere[1,3], and Maura Sassetti[1,3] — [1]University of Genova, Italy — [2]University of Luxembourg, Luxembourg — [3]SPIN-CNR, Genova, Italy — [4]NEST, Pisa, Italy

The possibility to inject a single electron into ballistic 1D conductors is at the basis of the new and fast developing field of electron quantum optics. In this respect, helical edge states of topological insulators can be used as electronic waveguides and would be an ideal playground [1,2].

Here we thus study and characterize the tunneling of a single electron from a mesoscopic capacitor into a couple of interacting helical edge channels [3]. The injection process leads to the creation of a pair of fractional excitations travelling in opposite directions. Their charge and energy profiles are analyzed. We also show that the energy partitioning between the two fractional excitations depends both on the interaction strength and on the injection parameters. Interestingly, this allows for a situation in which energy and charge mainly flow in opposite directions. In addition, such peculiar behavior of energy partitioning suggests that it can be also used as a tool to probe features of out-of-equilibrium systems [4].

[1] G. Fève et al., Science 316, 1169 (2007)
[2] D. Ferraro et al., PRB 89, 075407 (2014)
[3] A. Calzona et al., PRB 94, 035404 (2016)
[4] A. Calzona et al., arXiv:1610.04492

MA 13.9 Mon 17:15 HSZ 304

Solitons in one-dimensional lattices with a flat band — •Dario Bercioux[1,2], Omjyotu Dutta[1], and Enrique Rico[2,3] — [1]Donostia International Physics Center (DIPC), E-20018 San Sebastián, Spain — [2]IKERBASQUE, Basque Foundation for Science, Maria Diaz de Haro 3, 48013 Bilbao, Spain — [3]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, E-48080 Bilbao, Spain

We investigate the spectral properties of a quasi-one-dimensional lattices in two possible dimerization configurations [1]. Both configurations are characterized by the same lattice topology and the same spectra containing a flat band at zero energy. We find that, one of the dimerized configuration has similar symmetry to an one-dimensional chain proposed by Su-Schrieffer-Heeger [2] for studying solitons in conjugated polymers. Whereas, the other dimerized configuration only shows non-trivial topological properties in the presence of chiral-symmetry breaking adiabatic pumping.

[1] D. Bercioux, O. Dutta & E. Rico, arXiv:1609.06292.
[2] W. P. Su, J. R. Schrieffer, & A. J. Heeger Phys. Rev. Lett. **42**, 1698 (1979).

MA 13.10 Mon 17:30 HSZ 304

Local nature of Quantized Hall Effect — •Afif Siddiki — Mimar Sinan Fine Arts University, Physics Department, Sisli-Istanbul, Turkey 34380

Here, we investigate the electrostatic properties of two dimensional electron system (2DES) in the integer quantum Hall regime. As it is well known, the Landau quantization emerges from strong perpendicular magnetic fields. The (Landau) energy levels are broadened due to impurities, which we embedded their effects in density of states (DOS). As a simple model, DOS have two different forms: the Gaussian and semi-elliptic descriptions, i.e. the self consistent Born approximation (SCBA). Having in hand DOS, we obtain both the longitudinal and Hall (transversal) conductivities (σ_L, σ_H) utilizing Thomas-Fermi-Poisson approximation to calculate the charge density profile and Drude model to obtain transport coefficients. Since, the definition of capacitance is closely related with compressibility, (local) screening properties of 2DES is extremely important. Here we numerically simulate a translational invariant Hall bar subject to high magnetic fields which is perpendicular to the plane of the 2DES using realistic parameters extracted from the related experiments. Using the above mentioned approaches the local capacitances are calculated, numerically. Our findings are in perfect agreement with the related experiment which is based on a dynamic scanning capacitance microscopy technique.

MA 13.11 Mon 17:45 HSZ 304

Properties of non-abelian hierarchy states in the fractional quantum Hall effect — •Yoran Tournois and Maria Hermanns — Institute for Theoretical Physics, Cologne, Germany

The fractional quantum Hall effect is one of the paradigmatic examples of topological order in condensed matter physics. While the physics of the fractional quantum Hall effect is well understood in the lowest Landau level by means of the Haldane-Halperin hierarchy, a general method to describe the properties of quantum Hall liquids in the second Landau level is lacking. These are of particular interest, as it is believed that they may harbor exotic excitations - non-abelian anyons. In this talk, we consider a general class of model wave functions, which were recently proposed as a generalization of the Haldane-Halperin hierarchy. While these are conjectured to describe non-abelian quantum Hall liquids, many of their properties are not manifest and thus previously unknown. We determine their properties using a variety of methods. In particular, we derive the explicit conformal field theory description of the model wave functions, which reveals the non-abelian braiding statistics of the quasiparticles as well as the edge theory.

MA 14: Magnetization / Demagnetization Dynamics II

Time: Monday 15:00–17:30 Location: HSZ 401

MA 14.1 Mon 15:00 HSZ 401

***Ab initio* theory of laser-induced magnetization in longitudinal and transversal configurations** — •Marco Berritta, Ritwik Mondal, and Peter M. Oppeneer — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

All-optical helicity-dependent magnetization switching has recently emerged as a promising way to control a material's magnetization using short optical laser pulses[1]. A precise understanding of the underlying mechanism has not yet emerged, but it is expected that a nonlinear opto-magnetic effect, the inverse Faraday effect (IFE), plays a role to coherently induce magnetization which assists switching. We have recently developed a quantum theory[2] to calculate *ab initio* the laser-induced magnetization in ferromagnetic materials in longitudinal configuration, i.e., when the incoming light is parallel to the magnetization direction. We have extended our theory to treat the transversal configuration where the induced magnetization is normal to the existing magnetization and will thus exert a torque on it. Moreover, we have extended the theory to compute the site- and element-resolved contributions of the IFE in multi-sublattice compounds. Our results provide a roadmap for engineering suitable compounds and manipulating them in optimal configuration to achieve ultrafast magnetization switching.

[1] C.-H. Lambert *et al.*, Science **345**, 1337 (2014); R. John *et al.*, arXiv: 1606.08723 (2016).
[2] M. Berritta, R. Mondal, K. Carva, P.M. Oppeneer, Phys. Rev. Lett. **117**, 137203 (2016).

MA 14.2 Mon 15:15 HSZ 401

Temperature-dependent Mueller matrix measurements of the optical constants of Ni near the Curie temperature — Farzin Abadizaman, Jaime M. Moya, and •Stefan Zollner — New Mexico State University, Las Cruces, NM, USA

Previous ellipsometry measurements (S. Zollner *et al.*, Appl. Surf. Sci. in print) of the pseudo-dielectric function of bulk and thin-film Ni at 1.96 eV as a function of temperature reported a discontinuity near the Curie temperature while heating the sample from 80 to 800 K. The discontinuity disappeared when cooling the sample. Our previous experiments were unable to distinguish between the off-diagonal response (magneto-optical Kerr effect) and the on-diagonal response (Drude conductivity and interband transitions). We therefore performed more advanced temperature dependent ellipsometry measurements to determine the Mueller matrix response of bulk and thin-film Ni. We also carried out control measurements on a Ni:V alloy (which is not ferromagnetic for a sufficiently large V content) and other materials to determine the systematic and random errors of the Mueller matrix elements using our J.A. Woollam variable-angle-of-incidence (VASE) ellipsometer.

MA 14.3 Mon 15:30 HSZ 401

All optical Switching of magnetization on FePt nanoparticle using ultrafast lasers: A rate theory approach for the mechanism — •Robin John[1], Marco Beritta[2], Denise Hinzke[3], Cai Mueller[4], Tiffany Santos[5], Henning Ulrichs[6], Jakob Walowski[1], Ritwik Mondal[2], Oksana Chubykalo-Fesenko[7], Pablo Nievess[7,8], Jeffrey McCrod[4], Peter M Oppeneer[2], Ulrich Nowak[3], and Markus Muenzenberg[1] — [1]Institut fur Physik, Felix-Hausdorffstrasse-6, Ernst-Moritz-Arndt Universitat Greifswald, Germany — [2]Department of Physics and Astronomy, Uppsala University, P. O. Box 516, SE-75120, Uppsala, Sweden — [3]Department of Physics, University of Konstanz, Konstanz, Germany — [4]Institute for Materials Science, Kiel University, Germany — [5]Western Digital Corporation, San Jose, California, USA — [6]I. Phys. Institut, Georg-August-University Goettingen, Germany — [7]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain — [8]ICCRAM, Universidad de Burgos, Burgos, Spain

Ultrafast Magnetization dynamics and all optical switching has been attracting the attention for a few years. Our work emphasizes the fact that the switching of magnetization on FePt granular medium is not merely thermally driven by laser induced heating, but also with a major contribution from helicity dependence in the form of inverse Faraday effect and magnetic circular dichroism. We show both experimentally and theoretically that the magnetization switching is a stochastic process. We have developed a complete multi-scale model to describe helicity dependent AOS in FePt nanoparticle recording medium.

MA 14.4 Mon 15:45 HSZ 401

Separation of optical and magnetic response in Au films excited by circularly polarized laser pulses — •D. Schummer[1], S. Sakshath[1], M. Barkowski[1], D. Steil[2], F. Ganss[3], M. Albrecht[3], B. Stadtmüller[1], S. Mathias[2], and M. Aeschlimann[1] — [1]TU Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]University of Göttingen, Friedrich Hund Platz 1, 37077 Göttingen, Germany — [3]University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg, Germany

Circularly polarized femtosecond laser pulses have been successfully used to induce intriguing phenomena such as all-optical switching (AOS) of magnetization. In particular, the symmetry breaking effect which dictates the orientation of the magnetization reversal after optical excitation is still heavily debated. One possible explanation is based on the inverse Faraday effect which can induce a transient magnetization in the material by the circularity of the laser light. This phenomena was also predicted for metals with strong spin-orbit coupling such as Au or Pt [1]. In this context, we have studied the subpicosecond magnetic response of Au to a circularly polarized femtosecond laser pulse. As optical probe, we use the time resolved complex magneto-optical Kerr effect. This approach allows us to separate different contributions of the transient magneto-optical response and to identify a transient magnetic state induced by circularly polarized femtosecond laser excitation.

Reference: [1] Berritta et al, Phys. Rev. Lett.117, 137203 (2016)

MA 14.5 Mon 16:00 HSZ 401

Element-resolved study on the influence of a magnetic dopant on the exchange interaction in FePt on ultrashort timescales — •Moritz Barkowski[1,2], Daniel Steil[3], Lisa Walter[1], Steffen Eich[1], Jurij Urbancic[1], Benjamin Stadtmüller[1,2], Manfred Albrecht[4], Martin Aeschlimann[1], and Stefan Mathias[3] — [1]TU Kaiserslautern, Erwin-Schroedinger Strasse 46,67663 Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz — [3]University of Göttingen, I. Physikalisches Institut, 37077 Göttingen — [4]University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg

In this study, we investigate the optically induced ultrafast demagnetization dynamics of a FePt alloy doped with Mn atoms on the characteristic timescale of the exchange interaction of a few femtoseconds. We use high harmonic generation with photon energies in the XUV to gain elemental resolution in a femtosecond magneto-optical Kerr-effect experiment [1] in transversal geometry. Following up on earlier experiments, which showed the importance of the exchange interaction in the demagnetization process in alloys [2,3], we see clear differences in the dynamical responses of the three elements Fe, Pt, and Mn. Our results suggest, that the exchange coupling between the magnetic moments of the FePt alloy and the Mn dopant changes on ultrashort timescales.

References

[1] Chan L.-O., Phys.Rev.Letters 103,011005 (2009)
[2] S. Mathias, PNAS 109, 4792-4797 (2012)
[3] A.J. Schellekens, Phys.Rev. B 87, 020407(R) (2015)

15 min. break

MA 14.6 Mon 16:30 HSZ 401

Inhomogeneous laser induced ultrafast magnetization dynamics at Co/Cu(001) films analyzed by interface-sensitive nonlinear magneto-optics — •Jinghao Chen, Andrea Eschenlohr, Jens Wieczorek, Shunhao Xiao, Alexander Tarasevitch, and Uwe Bovensiepen — Fakultät für Physik, Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

A femtosecond laser pulse drives metallic ferromagnets into non-equilibrium and causes an ultrafast quenching of the magnetization [1]. The optically excited magnetization dynamics is analyzed via time-resolved optical magnetization-induced second harmonic generation (mSHG). In this work we report a systematic thickness dependent study of Co/Cu(001) in the Co thickness range from 0.4 to 10 nm. We identify two interface contributions and apply a simple model to separate the contributions from the vacuum/Co und Co/Cu interfaces to the total SHG yield. The transient magnetization dynamics of the Co film in the first 300 fs is dependent on the film thickness. We find that for Co film thickness $d < 3$ nm the vacuum/Co interface is more strongly demagnetized than the Co/Cu interface, for $d > 3$ nm i.e. above the spin dependent inelastic mean free path [2], the Co/Cu interface has a stronger demagnetization than the vacuum/Co interface, which implies that the majority spins at the interface escape into the conducting substrate [3].

[1] E. Beaurepaire et al., Phys. Rev. Lett. **76**, 4250 (1996) [2] V. P. Zhukov et al., Phys. Rev. B **73**, 125105 (2006) [3] J. Chen et al., http://arxiv.org/abs/1608.03842.

MA 14.7 Mon 16:45 HSZ 401

All-optical switching and ultrafast magnetization dynamics in Pt/Co multilayers — •Umut Parlak, Roman Adam, Moritz Plötzing, Daniel E. Bürgler, and Claus M. Schneider — Peter Grünberg Institut, PGI-6, Research Centre Jülich, 52425, Jülich, Germany

The observation of all-optical switching (AOS) in ferromagnetic thin films raised many questions concerning the nature of magnetization reversal. Recent studies suggest that the interplay between light-induced sample heating and light helicity plays a crucial role in achieving an efficient switching [1]. We investigate the effect of laser pulse duration, number of pulses, fluence and polarization state of the beam on the AOS efficiency in $[Pt/Co]_N$ multilayers, where N varies from 3 to 9. The response of the samples to the laser light was detected using a magneto-optical Kerr effect (MOKE) microscope combined with the laser system. Our results indicate that AOS probability depends on precise tuning of the above-mentioned laser parameters, and it scales with the number of pulses per illuminated area. Moreover, the dynamics of the AOS and demagnetization processes have been found to depend not only on laser fluence and external magnetic field, but also the multilayer repetition number. [1] Cornelissen, T. D., Córdoba, R., and Koopmans, B. (2016). Microscopic model for all optical switching in ferromagnets. Applied Physics Letters, 108(14), 142405.

MA 14.8 Mon 17:00 HSZ 401

Effect of spin-orbit coupling on femtosecond spin dynamics in NiPd magnetic alloys — •Seung-gi Gang[1], Roman Adam[1], Moritz Plötzing[1], Moritz von Witzleben[1], Christian Weier[1], Daniel E. Bürgler[1], Pablo Maldonado[3], Stefan Mathias[4], Martin Aeschlimann[2], Peter M. Oppeneer[3], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Research Centre Jülich, 52425 Jülich, Germany — [2]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [3]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden — [4]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany

We studied optically-induced femtosecond spin dynamics in NixPd1-x magnetic alloys with laser pulses (1.55 eV) by recording the time evolution of the transversal magneto optical Kerr effect (T-MOKE) signal at Ni M2,3- and Pd N2,3-absorption edges using extreme ultraviolet (20 to 72 eV) pulses. In static measurements, the Pd subsystem show an magnetic asymmetry with an opposite sign compared to the ferromagnetic Ni. Dynamics of the Ni-subsystem show that increase of the Pd concentration results in a drop of the demagnetization time τM. The decreased τM cannot be explained by the simple τM ~ u/TC scaling, which is typically observed in single-species materials by considering only magnetic moment u and Curie temperature TC. However, the observed behavior can be well understood within a spin-flip scattering framework, if changes of the spin-flip probability due to the enhanced spin-orbit coupling of the heavy Pd atoms is considered.

MA 14.9 Mon 17:15 HSZ 401

Direct observation of dipolar-exchange magnon and phonon spectra in arbitrary magnetized yttrium-iron-garnet films — •Dmytro A. Bozhko[1,2], Philipp Pirro[1], Halyna Musiienko-Shmarova[1], Ihor I. Syvorotka[3], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Department of Crystal Physics and Tehnology, SRC "Carat", Ukraine

We report on results of the experimental investigation of thermal spectra of dipolar-exchange magnons and transversal acoustic phonons in an obliquely magnetized yttrium-iron-garnet (YIG) thin film. Magnons and phonons propagating along the projection of the bias magnetic field $\vec{H}$ ($H = 2500\,\mathrm{Oe}$) on the film surface were probed by wavevector-resolved Brillouin light scattering spectroscopy. The YIG film of $5.6\,\mu$m thickness was grown in the (111) crystallographic plane on a gadolinium-gallium-garnet substrate by liquid-phase epitaxy. It has been found that in the case of oblique magnetization the spectrum of long-wavelength dipolar magnons splits into forward and backward spin-wave modes with positive and negative group velocities, respectively. With decrease of the magnon wavelength, these modes merge into a single exchange branch. This transition from the dipolar to the exchange regimes, which is still not described by existing theoretical models, is analyzed and discussed. The work is supported by the DFG within the SFB/TR 49.

MA 15: Magnetic Heuslers, Half-metals and Oxides (jointly with TT)

Time: Monday 15:00–18:30 Location: HSZ 403

MA 15.1 Mon 15:00 HSZ 403

Giant anomalous Hall effect in Heusler compounds — •Kaustuv Manna[1], Rolf Stinshoff[1], Ting-Hui Kao[1], Nitesh Kumar[1], Chandra Shekhar[1], Jayita Nayak[1], Sunil Wilfred DSouza[1], Sanjay Singh[1], Gerhard H. Fecher[1], Stuart S. P. Parkin[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle, Germany

The Co-Based Heusler compounds have drawn considerable interest in last few years for the spintronics application due to the prediction of large anomalous Hall effect (AHE) as well as spin Hall effect [1]. For many of the samples like Co_2MnAl, Co_2MnGa etc. formation of the Weyl points near Fermi energy was proposed to be the origin for such fascinating behaviour [2]. Here we report the giant anomalous Hall effect in Co_2MnGa single crystals. The sample crystallizes with $Fm\bar{3}m$ which hold the inversion symmetry and the AHE observed ~ 1200 S cm^{-1} at 2 K. The ferromagnetic moment found $\sim 4.23\ \mu_B/fu$. On the contrary, for the systems where the inversion symmetry is broken, like Mn_2CoGa [$F\bar{4}3m$], there is no Weyl point in the band structure. Interestingly we don't observe any AHE at 2 K though the system possess ferromagnetic moment of $\sim 2.27\ \mu_B/fu$.

[1]Jen-Chuan Tung and Guang-Yu Guo, New J. Phys. **15**, 033014 (2013).
[2]J. Kubler and C. Felser, Europhys. Lett. **114**, 47005 (2016).

MA 15.2 Mon 15:15 HSZ 403

Magnetic field assisted heat treatment — •Franziska Seifert[1], Bernd Büchner[1,2], and Sabine Wurmehl[1] — [1]Leibniz Institute for Solid State Research Dresden, Germany — [2]Technische Universität Dresden, Germany

The convetionell way to improve or tailor the structural and physical properties of a material is, in most of the cases, high temperature annealing. It is also possible to anneal the material at a certain magnetic field at room temperature. With our device we combine both, magnetic field and high temperature treatments. We are able to tailor the magnetic properties by applying a magnetic field during high temperature annealing. Especially in multiphase materials, we can favour particular one phase, which determines the magnetic properties. This annealing technique is very interesting for shape memory alloys, magnetocaloric, hardmagnetic or highly spin polarized materials. Our preliminary results will be discussed.

MA 15.3 Mon 15:30 HSZ 403

Stability of a highly spin polarized surface resonance of Co_2MnSi at spin-valve interfaces — •Christian Lidig[1], Alexander Kronenberg[1], Andrei Gloskovskii[2], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Deutsches Elektronen-Synchrotron DESY, 22603 Hamburg, Germany

The magnitude of the spin polarization of ferromagnetic materials is a key property for their application in spin transport-based electronics. However it is not the bulk, but the interface of the material, which is relevant for applications. Investigating thin films of Co_2MnSi (CMS) by spin-resolved UPS and spin-integrated HAXPES, we recently observed a high spin polarization at room temperature in a wide energy range below the Fermi energy, which is related to a stable highly spin polarized surface resonance[1,2]. Correspondingly, CMS / Ag / CMS spin valves show large GMR values[3]. However, the use of alternative spacer layers like Cr[4] always resulted in strongly reduced GMR values. A characteristic spectral feature close to the Fermi edge in HAXPES is related to the surface resonance[1]. This spectral feature is completely suppressed at CMS interfaces with Al and Cr and diminished in combination with Cu. However, it is fully conserved at epitaxial interfaces with Ag, explaining the superior magnetoresistance of spin-valves with this materials combination. [1] M. Jourdan et al., Nat. Commun. **5**, 3974 (2014). [2] J. Braun et al., Phys. Rev. B **91**, 195128 (2015). [3] Y. Sakuraba et al., Appl. Phys. Lett. **101**, 252408 (2012). [4] K. Yakushiji et al. Appl. Phys. Lett. **88**, 222504 (2006).

MA 15.4 Mon 15:45 HSZ 403

Defect-induced magnetic structure of CuMnSb — •Frantisek Maca[1], Josef Kudrnovsky[1], Vaclav Drchal[1], and Ilja Turek[2] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Charles University, Faculty of Mathematics and Physics, Praha, Czech Republic

We have investigated the magnetic phases of CuMnSb Heusler alloy with defects which exist in real experimental conditions. Total energy calculations confirm that the AFM[100]-phase is the ground state for the ideal CuMnSb in contrast to the experimentally observed AFM[111]-phase. Calculated formation energies indicate as possible candidates for defects the Cu-Mn swaps for the stoichiometric alloy and Mn-antisites on Cu-lattice and Mn-interstitials for Mn enriched alloys.

The total energies of various magnetic phases of CuMnSb with defects were determined using two different structural models, namely, the full-potential supercell approach and the alloy model employing the coherent potential approximation (CPA). We have found that the AFM[111]-ground state is stabilized for a low critical impurity concentrations approximately 3% . We have also investigated the influence of defects on the exchange interactions among Mn-moments and the stability of magnetic order by using the Heisenberg model Hamiltonian. The stability of the AFM[111] phase is in all cases enhanced by electron correlations in narrow Mn-bands treated here in the static limit (LDA+U).

MA 15.5 Mon 16:00 HSZ 403

Magnetotransport in Half-Metallic Manganese Ruthenium Gallium — •Ciaran Fowley[1], Kiril Borisov[2], Gwenael Atcheson[2], Yong-Chang Lau[2], Naganivetha Thiyagarajah[2], Rodolfo Gallardo[3], Jurgen Lindner[1], Zhaosheng Wang[4], Erik Kampert[4], Mike Coey[2], Plamen Stamenov[2], Karsten Rode[2], and Alina Maria Deac[1] — [1]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328, Germany — [2]AMBER and School of Physics, Trinity College Dublin, Dublin 2, Ireland — [3]Universidad Técnica Federico Santa María, Valparaíso, Chile — [4]High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, 01328, Germany

The recently discovered fully-compensated half-metal, manganese-ruthenium-gallium (MRG), is a very promising material for spintronics. It possesses tunable magnetic moment, high magnetic anisotropy field and high spin polarisation. Here, we use the extraordinary Hall effect and longitudinal magnetoresistance to characterise the properties of MRG. Experiments are carried out in pulsed magnetic fields up to 60 T at the Dresden High Magnetic Field Laboratory (HLD). The spin-flop transition, as well as a large spontaneous Hall angle (over 2%) is observed. The magneto-transport in MRG is shown to be dominated by one sublattice only. The spontaneous Hall angle is non-zero even at the magnetic compensation temperature (i.e. when the total magnetic moment is zero). MRG behaves magnetically like an antiferromagnet and electrically as a normal ferromagnet with a sizeable spin-polarisation.

MA 15.6 Mon 16:15 HSZ 403

Tunneling Magnetoresistance in MnRuGa based Magnetic Tunnel Junctions — •Aleksandra Titova[1,2], Ciaran Fowley[1], Kiril Borisov[3], Davide Betto[3], Yong Chang Lau[3], Nivetha Thiyagarajah[3], Gwenael Atcheson[3], Michael Coey[3], Plamen Stamenov[3], Karsten Rode[3], Jürgen Lindner[1], Jürgen Fassbender[1,2], and Alina Deac[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Germany — [3]Trinity College, Dublin, Dublin, Ireland

Some intermetallic Heusler compounds display high spin polarization and low magnetic moment. Thin-film samples can possess huge uniaxial anisotropy fields, exceeding tens of teslas. This, combined with their tuneable properites, make these materials very attractive for THz based spin-transfer-torque oscillators. Recently new material from this family was discovered - MnRuGa (MRG) - the first experimentally achieved fully-compensated half-metallic ferrimagnet. Here we show that MRG can be integrated in perpendicular anisotropy magnetic tunnel junctions stacks. Tunneling magnetoresistance (TMR) ratios up to 40% are observed. We also demonstrate that the TMR exists even when the net magnetization of MRG is strictly zero, implying that, at compensation, MRG exhibits a sizable spin polarization. The role of different diffusion barrier layers between MRG and the tunneling barrier as well as annealing temperature was investigated.

This work is supported by the Helmholtz Young Investigator Initiative Grant No. VH-N6-1048.

15 min. break.

MA 15.7 Mon 16:45 HSZ 403

Influence of grain boundaries on cohesive and magnetic properties in the inverse Heusler phase Fe_2CoGa — •Georg Krugel, Daniel Urban, Wolfgang Körner, and Christian Elsässer — Fraunhofer Institute for Mechanics of Materials IWM, Wöhlerstraße 11, 79108 Freiburg, Germany

Heusler phases are promising candidates in the search for a rare-earth free hard-magnetic compound allowing high Curie temperatures. Experimentally, they are often found to be brittle and the effect of their microstructure on the material properties is not yet understood in detail.

Using DFT calculations we investigate the effect of grain boundaries (GB) on the mechanical and magnetic properties of the inverse Heusler phase Fe_2CoGa as a case study. Four different GBs are studied and several different translation states taken into account for each of them to sample the gamma surface. The GB excess volume, the formation energy of the GB and the cohesion energies of the grains are calculated and compared in order to shed more light onto the influence of GB on the mechanical properties of Heusler phases. For an understanding of the behaviour of magnetism at the GB the local atomic configurations are analysed together with the atomic magnetic moments. Moreover, we calculate the magnetic anisotropy energies for the energetically most favorable configurations. Our results support experimental efforts to determine tailored synthesis routes.

MA 15.8 Mon 17:00 HSZ 403

Study of compensated ferrimagnetic Heusler materials $Mn_{3-x}Pt_xGa$ — •Vivek Kumar[1], Ajaya K. Nayak[1,2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

Compensated ferrimagnets with large spin polarization and high ordering temperature are perfect candidates for realization of antiferromagnetic spintronics. These materials with additional perpendicular magnetocrystalline anisotropy can be ideal candidates for spin transfer torque applications. In this direction Heusler materials find special attention where chemical disorder can be used as an engineering tool to improve desired properties. The tetragonal Mn_3Ga is an interesting

candidate as a starting material which exhibits a high Curie temperature (T_C). It is theoretically predicted that substitution of Mn with a late transition metal can lead to a decrease in the total magnetic moment [1]. Here we present the structural and magnetic properties of single phase bulk tetragonal $Mn_{3-x}Pt_xGa$ Heusler materials for x varying from 0 to 0.6. We have found that the tetragonal distortion increases with increasing Pt concentration, indicating stabilization of the tetragonal phase with Pt substitution. With increasing Pt concentration the total magnetic moment systematically decreases and reach a compensation point around x=0.6. Although the magnetic ordering temperature displays a slight reduction with Pt substitution the compensated sample exhibits a T_C well above room temperature.
[1]R. Sahoo *et al.*, Adv. Mat. **28**, 8499 (2016).

MA 15.9 Mon 17:15 HSZ 403

High quality Yttrium Iron Garnet thin films by room temperature deposition and annealing in argon atmosphere — •Christoph Hauser[1], Christian Eisenschmidt[1], Hakan Deniz[2], and Georg Schmidt[1,3] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Interdisziplinäres Zentrum für Materialwissenschaften, Halle, Germany

We have recently [1] shown that depositing Yttrium Iron Garnet by Pulsed Laser Deposition at room temperature and subsequent annealing in an oxygen atmosphere results in fully epitaxial layers. The layers show extremely low damping and very narrow linewidth in Ferromagnetic Resonance, even for thin layers. Here we show that annealing in oxygen is not mandatory. Also annealing in argon results in high quality layers. For a 63 nm YIG layer a linewidth of 2.26 Oe @ 9.6GHz and a damping of $1.61 \cdot 10^{-4}$ is observed in FMR. Structural characterization indicates high crystalline quality and no visible defects. [1] Hauser *et al.*, Sci. Rep. 6, 20827 (2016)

MA 15.10 Mon 17:30 HSZ 403

Colossal increase in the magnetic moment of NiCo2O4 films via He-ion irradiation — •Parul Pandey[1], Yugandhar Bitla[2], Matthias Zschornak[1], Mao Wang[1], Chi Xu[1], Joerg Grenzer[1], Sibylle Gemming[1], Manfred Helm[1], Ying-Hao Chu[2,3], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum-Dresden -Rossendorf, Dresden, Germany — [2]National Chiao Tung University, Hsinchu, Taiwan — [3]Institute of Physics, Academia Sinica, Taipei, Taiwan

The spinel NiCo2O4 exhibits the unique combination of electrical conductivity, infrared transparency, electro catalytic activity, and ferrimagnetic order, which makes it an attractive material for spintronic applications. The NiCo2O4 thin-films electrical and magnetic properties can be manipulated from high temperature ferrimagnetic and metallic to low temperature ferromagnetic and insulating by changing the growth temperature. The high-quality epitaxial NiCo2O4 films were grown on MgAl2O4 (100) substrate at ~ 400°C exhibits metallic behavior accompanied by ferrimagnetic order with moment ~ 2 μB/fu. Here, we report the impact of He-ion irradiation with fluence ranging from 5*1015/cm2 - 3*1016/cm2 on these metallic NiCo2O4 films. The use of He-ion irradiation results in the coherent control of out-of-plane lattice parameter of these films without changing its in-plane lattice parameter. The comprehensive study of magnetization data reveals the magnetic moment in the irradiated films increases drastically to ~ 4 μB/fu. The X-ray absorption spectroscopic study also suggests the possible charge redistribution within the octahedral sites of the NiCo2O4 films which corroborate well with the increase in the magnetic moment.

MA 15.11 Mon 17:45 HSZ 403

Magnetic and structural properties in the spin-dimer system Ba0.1Sr2.9Cr2O8 — •Alsu Gazizulina[1], Diana Lucia Quintero Castro[2], and Andreas Schilling[1] — [1]Physik-Institut of University of Zurich, Zurich, Switzerland — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Sr3Cr2O8 and Ba3Cr2O8 are two insulating dimerizad antiferromagnets with the magnetic ions, Cr 5+, that lie on hexagonal bilayers with strong intradimer antiferromagnetic interaction. This leads to a singlet ground state and gapped triplet states. Intradimer interaction constant J0 strongly depends on the stoichiometry.

We report on the change of the structural and magnetic properties of a spin-dimer system, Sr3Cr2O8, by introducing chemical disorder. Two large single crystal of Ba(3-x)Sr(x)Cr2O8 with x=2.9 and x=2.8 have been grown in a four-mirror type optical floating-zone furnace. By performing magnetization, heat-capacity measurements we have studied structural and magnetic properties of these compounds. Our inelastic neutron scattering measurements of spin-dimer compound Ba0.1Sr2.9Cr2O8 determine the interaction constants and the spin gap. The intradimer interaction constant is found to be J0=5.327(1) meV, that about 8% smaller than for pure Sr3Cr2O8 compound. Spin gap is decreasing about 6% with introducing chemical disorder.

MA 15.12 Mon 18:00 HSZ 403

First principles study of orbital order in Mn doped FeV2O4 — Dibyendu Dey[1], •Tulika Maitra[2], and Arghya Taraphder[1] — [1]Department of Physics, Indian Institute of Technology, Kharagpur 721302, India — [2]Department of Physics, Indian Institute of Technology, Roorkee 247667, India

The long range orbital order in vanadium spinel oxides has been thoroughly debated by condensed matter physicists in recent years. MnV_2O_4 and FeV_2O_4 are two such compounds where the debate is centered around whether there are complex or real orbitals involved in the ordering process. In this context, we have investigated the long range orbital order in Mn doped FeV_2O_4 as a function of Mn doping (x). We have employed first-principles density functional theory (DFT) including Coulomb correlation (GGA+U) and spin-orbit interaction (GGA+U+SO) as well as the wannierization of our DFT derived vanadium d-bands for our analysis of the orbital order in these systems. We observe that for x$\leq$0.6, the orbital order at V sites consists of a linear superposition of d_{xz} and d_{yz} orbitals of the type dxz$\pm$dyz whereas for x $>$ 0.6, A-type ordering is observed. The effect of spin-orbit interaction on orbital ordering is found to be not significant in the entire range of doping studied indicating the absence of complex orbitals in the ordering[1]. We also analyze the orbital ordering from the Raman spectrum calculated using ab-initio phonon within the DFT framework and compare the same with the experimental observations.

Reference: [1] Dibyendu Dey, T. Maitra, and A. Taraphder; Phys. Rev. B 93, 195133 (2016)

MA 15.13 Mon 18:15 HSZ 403

Curie temperature of ultra-thin EuO films in proximity to a metal — Brian Tam, Andreas Reisner, Steffen Wirth, •Simone G. Altendorf, and Liu Hao Tjeng — Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany

A reduction of the thickness of ferromagnetic layers towards the ultra-thin limit goes along with a strong reduction of the Curie temperature thereby hindering potential technological applications. We study the possibility to compensate the lowering of the magnetic ordering temperature of ultra-thin EuO films by bringing them in close proximity to a metal, thereby trying to make use of the so-called image charge screening effect to increase the strength of the magnetic exchange interactions. We utilize the well-established Eu-distillation-assisted MBE growth method to prepare highly stoichiometric EuO films on YSZ substrates. By capping one half of each film with a Mg metal overlayer and the other half with MgO, we were able to directly determine the effectiveness of the proximity effect of the metal to influence the magnetic properties of ultra-thin ferromagnetic films.

MA 16: Spin Dynamics: Magnetic relaxation and Gilbert Damping

Time: Monday 17:30–18:45 Location: HSZ 401

MA 16.1 Mon 17:30 HSZ 401

Room Temperature Spin Pumping into Cobalt Doped Zinc Oxide Evidenced by Multifrequency FMR — •Martin Buchner, Taddäus Schaffers, Bastian Henne, Verena Ney, and Andreas Ney — Johannes Kepler Universität, Linz, Austria

A precessing magnetization in a ferromagnet returns to its equilibrium position due to Gilbert damping. This damping can be increased by spin pumping, an angular momentum transfer to an adjacent non ferromagnetic layer [1]. By performing ferromagnetic resonance (FMR) measurements increased damping will result in a broadening of the linewidth. In classical, resonator-based FMR setups there is no possibility to distinguish between increased damping due to spin pumping and inhomogeneous broadening effects. This can only be achieved when measuring a frequency dependent linewidth. In this contribution we use a setup which replaces the resonator by a coaxial cable that is short-circuited at the sample side [2]. The magnetic field is induced into the sample via a microwave near field affect. In a two layer system consisting of permalloy and highly Co doped ZnO [3] film, both resonance position and the linewidth of the FMR lines, change. In the measured frequency range a 75 % increased damping parameter is found.

[1] Y. Tserkovnyak et al. Phys. Rev. Lett. 88, 117601 (2002).
[2] F. M. Römer et al. Appl. Phys. Lett. 100, 092402 (2012).
[3] B. Henne et al. Sci. Rep. 5, 16863 (2015).

MA 16.2 Mon 17:45 HSZ 401

Lifetime of terahertz magnons in ultrathin ferromagnets: Temperature effects — Huajun Qin[1], •Khalil Zakeri Lori[2,1], Arthur Ernst[1], and Juergen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Heisenberg Spin-dynamics Group, Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, D-76131 Karlsruhe, Germany

Utilizing spin-polarized high resolution electron energy loss spectroscopy we investigate the temperature dependence of high-energy (terahertz) magnons, excited in an ultrathin ferromagnet. Both the energy and lifetime of terahertz magnons are measured as a function of temperature and across the magnetic transition temperature T_C. Similar to the magnons' energy, their lifetime decreases with temperature. The observed temperature-induced damping of terahertz magnons is discussed in terms of multi-magnon scattering mechanism. Our results indicate that the damping resulted from this mechanism can be comparable to the intrinsic Landau damping of the system. We demonstrate that although at T_C terahertz magnons are affected by different damping mechanisms, they still behave as well-defined collective excitations. We argue that the effects associated with the collective properties of terahertz magnons should eventually sustain at T_C and even beyond that.

MA 16.3 Mon 18:00 HSZ 401

Thermal emergence of laser induced spin dynamics for a Ni_4 cluster — •Stefan Sold[1], Wolfgang Hübner[1,3], Bhaskar Kamble[2], Georgios Lefkidis[1], and Jamal Berakdar[3] — [1]University of Kaiserslautern and Research Center OPTIMAS, Kaiserslautern, Germany — [2]Asia Pacific Center for Theoretical Physics, Pohang, Korea — [3]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Using *ab initio* quantum chemistry we study the interplay of thermally-induced and laser-induced dynamics on the highly correlated magnetic Ni_4 cluster. We find that due to this interplay new cooperative dynamics emerges, which is a result of the combination of the quantum coherences introduced to the system by the laser pulse and the electronic relaxation due to the bath: A bath temperature of $10 < T < 300$ can help induce a spin flip, in cases the laser alone cannot.

Technically we propagate the density matrix of the system within the Markovian approximation, where the Lindblad superoperator describes the coupling to the bath [1]. By isolating the various electronic and spin relaxation channels we identify two different time regimes, both for the spins and for the charges [2], which we further analyze. We thus derive and discuss all phenomenological relaxation constants. Our quantum-thermodynamics findings on this prototypic system pave the way toward possible molecular spin-caloritronic applications.

[1] G. Schaller and T. Brandes, Phys. Rev. A **78**, 022106 (2008)
[2] G. P. Zhang, W. Hübner, G. Lefkidis, Y. Bai, and T. F. George, Nature Phys. **5**, 499 (2009)

MA 16.4 Mon 18:15 HSZ 401

Relaxation of a classical spin coupled to a strongly correlated electron system — •Mohammad Sayad, Roman Rausch, and Michael Potthoff — I. Institut für Theoretische Physik, Universität Hamburg

Electron correlations are expected to have qualitatively new effects on the spin dynamics. Up to now, this has been studied only indirectly by computing the effect of the Coulomb interaction on the Gilbert damping. Here, we investigate correlation effects beyond an LLG-type approach. To this end, we consider a prototypical model with a classical spin which is anti-ferromagnetically exchange coupled to a Hubbard system and study the spin dynamics as a function of the local Coulomb interaction U. To address this quantum-classical hybrid problem, we propose a combination of a non-Markovian linear-response theory for the spin dynamics with time-dependent density-matrix renormalization group for the correlated electron system. In the metallic phase at quarter filling, we find two different channels for energy and spin dissipation, namely dissipation via correlated hopping and via excitations of local magnetic moments. For strong U, these become active on largely different time scales. While the overwhelming contribution to the Gilbert damping is due to magnetic excitations in the strong-U limit, the magnetic contribution is much smaller in general and even vanishes for infinite U as it is never activated. At half-filling and strong U, electron correlations lead to an incomplete spin relaxation on intermediate time scales. This represents a novel effect in a quantum-classical hybrid model which is similar to prethermalization.

MA 16.5 Mon 18:30 HSZ 401

Spin-lattice Relaxation of NV-Centers in Diamond — •Johannes Gugler and Peter Mohn — Center for Computational Materials Science TU Vienna

Nitrogen-Vacancy centers in Diamond exhibit a very long electronic spin-relaxation time T1. Thus, they are a promising candidate for solid-state qubit implementation. The temperature dependence of T1 at the mK-temperature scale was not understood up to now. We performed DFT-calculations to obtain the structural, electronic and phononic properties of the NV-center in Diamond to investigate on the spin-lattice relaxation rate. Using the numerically obtained wavefunctions we calculate the electron-phonon transition matrix element of first order time dependent perturbation theory. Taking into account spin-orbit coupling and the electronic screening of the electron-ion potential we obtain the right temperature dependence and order of magnitude for the experimentally found relaxation times.

MA 17: PhD Symposium: Quantum Magnets: Frustration and Topology in Experiment and Theory (jointly with Young DPG (jDPG)

Organizers: Boris Celan, Leonie Heinze, Niklas Casper, Jonas Richter, Benjamin Köhler (TU Braunschweig)

Quantum magnetism is a very active area of condensed matter physics. In the last decades, this fascinating field has highly profited from the fruitful interplay of experiment and theory. It is a genuinely interdisciplinary area of research, linking across many different subfield boundaries, ranging from condensed matter and statistical physics, via ultra cold atomic gases, spin- and heat caloritronics, classical and quantum information theory, to questions in material design and device technology. Frustrated quantum magnets can be realized in spin systems in which localized magnetic moments interact through competing exchange interactions that cannot be simultaneously satisfied. Such spin systems may be frustrated due to a multitude of reasons, e. g., quantum chemistry can lead to competing exchange paths or lattice geometry can induce frustration. Furthermore, spin-orbit interactions may lead to pseudo-spins with frustrating compass interactions and higher-order exchange can generate frustration through ring exchange. On the classical level frustration gives rise to a large degeneracy of the system ground state. Frustration occurs due to geometrical reasons or higher order exchange processes. On the quantum level this might lead to the emergence of unconventional solid and liquid phases with exotic excitations. In this context, the possibility of spin liquids is quite interesting from a theoretical as well as from an experimental point of view. While in early days spin liquids have merely been considered to be magnets which lack any type of long range order down to T=0, it has only been realized very recently that such liquids are a novel form of correlated matter which shows topological order and intimately linked to that, fractionalized excitations. In theory, the formation of such matter defies a description in terms of standard Ginzburg-Landau theory and it seems fair to say, that its physics is far from being understood. In experiment, first potentially promising candidates may have been synthesized, such as e. g. triangular magnets in organics, quantum spin ice on pyrochlores, and Kitaev model variants in iridates. Yet, the search for definite materials is still ongoing. All in all, the study of frustrated quantum magnets reveals new physics and generates contributions to the development of novel materials. The investigation of quantum magnets is however a challenging problem. On the theoretical side numerous sophisticated methods have been developed and applied to gain insight into the properties of spin models, e. g. emergent gauge, and topological field theories, DMRG methods, tensor networks, variational Monte-Carlo and others. On the experimental side extensive material design has to be combined with a multitude of state-of-art probes, like nuclear magnetic resonance (NMR) and muon spin resonance (mu-SR), RIXS, INS, Raman, electron and tunneling spectroscopies as well as transport, high magnetic field, and thermodynamic measurements in order to identify potentially interesting compounds.

Time: Tuesday 9:30–15:00 Location: HSZ 04

Welcome and Introduction

Invited Talk MA 17.1 Tue 9:45 HSZ 04
Frustrated Quantum Magnets: Theory — •Matthias Vojta — Technische Universität Dresden, Germany

This tutorial will cover theoretical concepts of frustrated magnetism. It will start from the classical degeneracies induced by strong geometric frustration, discuss order-by-disorder phenomena, and lay out ideas for quantum spin liquids. The emergence of fractionalized excitations and artificial gauge fields will be discussed using explicit microscopic models. Physical signatures of these emergent phenomena will be highlighted. Further topics will include frustration in metallic systems, quantum phase transitions in the presence of frustration, and the role of quenched disorder. Throughout the talk, links to concrete materials will be pointed out.

Invited Talk MA 17.2 Tue 10:30 HSZ 04
Ground State Selection in Quantum Pyrochlore Magnets — •Bruce D. Gaulin — McMaster University, Hamilton, Ontario, Canada

Rare-earth (RE) based cubic pyrochlore magnets, with composition $RE_2B_2O_7$, are characterized by having RE^{3+} ions decorate a network of corner-sharing tetrahedra, one of the canonical architectures supporting geometric frustration in three dimensions. For a given $RE_2B_2O_7$ series, such as with the non-magnetic $B=Ti^{4+}$, crystalline electric field effects give different anisotropies for the magnetic RE ion, while varying crystal chemistry results in different magnetic interactions. The combination of these two produces a remarkable diversity of exotic magnetic ground states across a series such as $RE_2Ti_2O_7$. I will describe this series of materials, and point out how local XY anisotropy gives rise to $S_{effective}$=1/2 quantum spins for $Yb_2Ti_2O_7$ and $Er_2Ti_2O_7$. These two quantum pyrochlore magnets display very different ground states, a highly disordered, candidate quantum spin ice state in $Yb_2Ti_2O_7$, and a non-linear Neel state selected by the "order-by-disorder" mechanism for $Er_2Ti_2O_7$, due to their net ferromagnetic and antiferromagnetic interactions, respectively. I will focus mainly on experimental techniques, principally neutron scattering and heat capacity measurements, that can provide microscopic information on both the ground state and the excitations within the exotic ground states which these materials display.

15 min. break

Invited Talk MA 17.3 Tue 11:30 HSZ 04
Effects of anisotropic exchange in strong spin-orbit coupled magnets — •Natalia Perkins — University of Minnesota, Minneapolis, USA

Recently, the Jackeli-Khaliullin Kitaev (JKK) materials on various two- and three-dimensional tri-coordinated lattices, which are believed to be proximate to the Kitaev Quantum spin liquid, have attracted a lot of attention. In all these materials, the geometry of the lattices with edge-sharing octahedra of ligand ions is such that it gives rise to the dominant Kitaev interactions between effective j=1/2 magnetic moments of the transition metal ions. Nevertheless, the experimental studies of the JKK materials have shown that at sufficiently low temperatures and ambient pressure all of them order magnetically. These findings suggest that experimentally relevant super-exchange models must contain other subdominant interactions between magnetic moments in addition to the Kitaev coupling. In my talk I will discuss the effects of these anisotropies. I will show that the Kitaev spin liquid is very fragile with respect to the both second neighbor Kitaev interaction and the off-diagonal symmetric exchange anisotropy. I will also show that the off-diagonal exchange anisotropy drives the model to a classical spin liquid phase, characterized by an extensive number of ground states and ultra-short, highly anisotropic spin-spin correlations.

Invited Talk MA 17.4 Tue 12:00 HSZ 04
Numerical Approaches to Frustrated Quantum Magnets — •Stephan Rachel — Institute for Theoretical Physics, TU Dresden, Germany

Frustrated magnetism is one of the most vibrant and exciting fields of modern condensed matter physics. In particular, frustrated magnets are the hiding places of quantum spin liquids, a state of matter which does not exhibit magnetic long-range order but which possesses fractionalized elementary excitations. In this talk, I will give an overview of the numerical methods available for the investigation of frustrated magnets and discuss advantages and limitations. In particular, I will focus on recent developments for the investigation of three-dimensional quantum magnets and the search of spin liquid states.

MA 17.5 Tue 12:30 HSZ 04
Thermal and spin transport properties of frustrated spin-1/2 chains in high magnetic fields — •Jan Stolpp[1], Christoph Karrasch[2], Shang-Shun Zhang[3], Cristian Batista[3], and Fabian Heidrich-Meisner[1] — [1]Arnold Sommerfeld Center for Theoretical Physics - Ludwig-Maximilians-Universität München — [2]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin — [3]Department of Physics, University of Tennessee, Knoxville, and Oak Ridge National Laboratory

We perform a full diagonalization study of frustrated spin-1/2 chains (i.e. spin-1/2 chains with nearest and next nearest neighbor interaction) in the presence of an external magnetic field. The thermal and spin conductivity are computed from Kubo formulae as a function of frustration and field strength. We are especially interested in the transport properties in the vector chiral phase that appears in the phase diagram at strong frustration and in a high field. We observe an enhanced low-frequency response in the high-field vector chiral phase which we trace back to a renormalization and enhancement of the characteristic velocity.

Lunch break

Invited Talk MA 17.6 Tue 13:45 HSZ 04
Nuclear Probes on Frustrated Magnets — •Philippe Mendels — Lab. Physique des Solides, Univ. Paris-Sud, Orsay, France

NMR and μSR are two local powerful probes which often complement thermodynamic and neutron studies. I will first briefly introduce these two techniques and the parameter ranges (pressure, temperature, field) in which they can operate. I will then show how they give access to important information in the case of frustrated magnets: magnetic ordering, phase diagrams and magnetic fluctuations, spin liquid phases, field induced spin textures, opening of spin gaps. This will cover various up to date cases, triangular magnets, quantum spin ice, spin liquids... In the last part of my talk, I will show on one emblematic example of a kagome antiferromagnet, herbertsmithite, $ZnCu_3(OH)_6Cl_2$, how NMR can separate the contribution of defects from that of intrinsic properties and the unique outcomes which such experiments can bring.

Invited Talk MA 17.7 Tue 14:15 HSZ 04
Complex spin structures and multifunctional magnetism — •Vivien Zapf — National High Magnetic Field Lab, Los Alamos National Lab

There has been a recent surge of interest in multiferroics where magnetism and ferroelectricity are coupled to each other. In particular, complex magnetic spin textures such as skyrmions and other non-coplanar spin patterns can produce the necessary symmetry breaking to couple to ferroelectricity. I will discuss spatial inversion symmetry breaking in quantum and classical magnets and the microscopic coupling mechanisms between magnetism and ferroelectricity. I will review work at the National High Magnetic Field Lab, charting the phase diagrams of frustrated, quantum, and other complex spin systems to extended temperature and magnetic field which, conjunction with theory, can reveal important underlying information about the magnetic Hamiltonian.

MA 17.8 Tue 14:45 HSZ 04
Dimensional reduction due to geometric frustration – a case study — •Ulrich Tutsch[1], Burkhard Schmidt[2], Lars Postulka[1], Bernd Wolf[1], Natalija van Well[1], Franz Ritter[1], Cornelius Krellner[1], Wolf Assmus[1], and Michael Lang[1] — [1]Physikalisches Institut, Goethe-Universität Frankfurt, SFB/TR 49, 60438 Frankfurt (M), Germany — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany

Theoretical studies suggest that the frustrating zigzag bonds between the spin chains in triangular-lattice Heisenberg antiferromagnets gives rise to one-dimensional behaviour as long as $J'/J \leq 0.7$. $Cs_2CuCl_{4-x}Br_x$ ($0 \leq x \leq 4$) represents a good realization of such a system where the ratio J'/J of the in-plane spin-spin exchange coupling constants varies from 0.30 ($x = 0$) to 0.63 ($x = 2$), thus providing a well-suited model system for testing the frustration-induced dimensional-reduction scenario.

Here, we present specific heat data below 1 K for the compounds $Cs_2CuCl_2Br_2$ and Cs_2CuCl_3Br, which, due to site-selective substitution, show a well-ordered halide sublattice. The results for zero magnetic field for these systems as well as for the border compounds $x = 0$ and $x = 4$ can be well described by the antiferromagnetic Heisenberg chain model, fully consistent with frustration-induced one-dimensional behaviour.

MA 18: Transport: Quantum Coherence and Quantum Information Systems - Theory (jointly with MA, HL)

Time: Tuesday 9:30–13:15 Location: HSZ 103

MA 18.1 Tue 9:30 HSZ 103
Adiabatic Quantum Simulations with Superconducting Qubits — •Nikolaj Moll, Panagiotis Barkoutsos, Daniel Egger, Stefan Filipp, Andreas Fuhrer, Marc Ganzhorn, Andreas Kuhlmann, Peter Müller, Marco Roth, Peter Staar, and Ivano Tavernelli — IBM Research – Zurich, Säumerstrasse 4, CH-8803 Rüschlikon, Switzerland

Quantum computing technology is improving fast and quantum computers with approximately 100 qubits appear feasible in the not so distant future. The quest for systems which profit of exponential speed-up and cannot be calculated on classical computers has recently triggered a lot of attention. Fermionic quantum systems, such as quantum chemistry or the Fermi-Hubbard model, are among the best candidates for exploiting the exponential speed-up. Such a quantum system can be implemented on a quantum computer based on superconducting qubits. However, the controlled realization of different types of interactions between qubits without compromising their coherence is essential. A coupling method between fixed-frequency transmon qubits can be achieved with the frequency modulation of an auxiliary capacitively coupled quantum bus. An adiabatic protocol for the Hydrogen molecule can be implemented on such a coupled qubit system.

MA 18.2 Tue 9:45 HSZ 103
Tunable, Flexible and Efficient Optimization of Control Pulses for Superconducting Qubits, part I - Theory — •Shai Machnes[1,2], Elie Assémat[1], David Tannor[2], and Frank Wilhelm[1] — [1]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Weizmann Institute of Science, 76100 Rehovot

Quantum computation places very stringent demands on gate fidelities, and experimental implementations require both the controls and the resultant dynamics to conform to hardware-specific ansatzes and constraints. Superconducting qubits present the additional requirement that pulses have simple parametrizations, so they can be further calibrated in the experiment, to compensate for uncertainties in system characterization. We present a novel, conceptually simple and easy-to-implement gradient-based optimal control algorithm, GOAT [1], which satisfies all the above requirements.

In part II we shall demonstrate the algorithm's capabilities, by using GOAT to optimize fast high-accuracy pulses for two leading superconducting qubits architectures - Xmons and IBM's flux-tunable couplers.
[1] S. Machnes, D.J. Tannor, F.K. Wilhelm and E. Assémat, ArXiv 1507.04261 (2015)

MA 18.3 Tue 10:00 HSZ 103

Tunable, Flexible and Efficient Optimization of Control Pulses for Superconducting Qubits, part II: Applications — Shai Machnes[1,2], •Elie Assemat[1], David Tannor[2], and Frank Wilhelm[1] — [1]Saarland University, Saarbrücken, Germany — [2]Weizmann Institute of Science, Rehovot, Israel

In part I, we presented the theoretic foundations of the GOAT algorithm [1] for the optimal control of quantum systems. Here in part II, we focus on several applications of GOAT to superconducting qubits architecture. First, we consider a control-Z gate on Xmons [2] qubits with an Erf parametrization of the optimal pulse. We show that a fast and accurate gate can be obtained with only 16 parameters, as compared to hundreds of parameters required in other algorithms. We present numerical evidences that such parametrization should allow an efficient in-situ calibration of the pulse. Next, we consider the flux-tunable coupler by IBM [3]. We show optimization can be carried out in a more realistic model of the system than was employed in the original study, which is expected to further simplify the calibration process. Moreover, GOAT reduced the complexity of the optimal pulse to only 6 Fourier components, composed with analytic wrappers.

[1] S. Machnes et al., ArXiv 1507.04261v1 (2015)
[2] R. Barends et al., Phys. Rev. Lett. 100, 080502 (2013)
[3] D. C. McKay et al., ArXiv 1604.0307v2 (2016)

MA 18.4 Tue 10:15 HSZ 103

Symmetry Benchmarking of Quantum Algorithms — •Tobias Chasseur Chasseur[1], Felix Motzoi[1,2], Michael Kaicher[1], Pierre-Luc Dallaire-Demers[1], and Frank Wilhelm[1] — [1]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark

Scalable and robust benchmarking of quantum gates is essential on the path to a useful quantum computer, as current candidates such as superconducting qubit systems are set to leave the few qubit regime in the near future. Randomized Benchmarking and related approaches provide solutions for specific gates such as the Clifford group or a limited number of qubits; however a tool for benchmarking arbitrary gates without exponential scaling in the number of qubits seems prohibited by the inherent power of quantum computation. In this work we present a symmetry benchmarking protocol to estimate the implementation fidelity of specific algorithms with polynomial scaling. The proposed protocol relies on unitary 1-designs on the eigenspaces of algorithm-specific preserved quantities, as well as sequence structures similar to Randomized Benchmarking. It benchmarks the symmetry preservation of the implementation as an indicator for the overall fidelity. We demonstrate the protocol for the specific example of algorithms consisting of number preserving gates.

MA 18.5 Tue 10:30 HSZ 103

Implementation of Quantum Stochastic Walks — •Peter Schuhmacher[1], Luke Govia[2], Bruno Taketani[1], and Frank Wilhelm[1] — [1]Universität des Saarlandes, Saarbrücken, Germany — [2]Department of Physics, McGill University, Montreal, Quebec, Canada

Quantum walks are one of the most prominent frameworks in which to design and think about quantum algorithms. Both the continuous- and discrete-time versions have been shown to provide speed-up over classical information processing tasks, and can be regarded as universal quantum computers. Classical (probabilistic) and quantum unitary random walks yield different distributions due to interference effects. Combining the two, stochastic quantum walks (QSW) can be defined in an axiomatic manner to include unitary and non-unitary effects, and include both classical and quantum walks as limiting cases. While a general purpose quantum computer is still far over the horizon, intermediary technologies have been emerging with the promise to breach classical limitations. Within these, artificial intelligence is one exciting field where the use of quantum physics can lead to important improvements. Here, we focus on the physical realizability of both kinds of quantum stochastic walks (continuous-time and discrete-time).

MA 18.6 Tue 10:45 HSZ 103

Normal metal traps for superconducting qubits — •Roman-Pascal Riwar[1,2], Amin Hosseinkhani[1,3], Luke D. Burkart[2], Yvonne Y. Gao[2], Robert J. Schoelkopf[2], Leonid I. Glazman[2], and Gianluigi Catelani[1] — [1]Forschungszentrum Jülich, Germany — [2]Yale University, USA — [3]RWTH Aachen University, Germany

The coherence time of superconducting qubits is intrinsically limited by the presence of quasiparticles. While it is difficult to prevent the generation of quasiparticles, keeping them away from active elements of the qubit provides a viable way of improving the device performance. We develop theoretically and validate experimentally a model for the effect of a single small trap on the dynamics of the excess quasiparticles injected in a transmon-type qubit. By means of this model, we show that for small traps, increasing the size shortens the evacuation time of quasiparticles from the transmon. We further identify a characteristic trap size above which the evacuation time saturates to the diffusion time of the quasiparticles. In the diffusion limit, the geometry of the qubit and the trap become relevant. We compute the optimal trap number and placement for several realistic geometries. Finally, our estimates show that the dissipation introduced by the presence of normal metal traps is well below the losses observed in the transmon.

MA 18.7 Tue 11:00 HSZ 103

Proximity Effect in Normal-Metal Quasiparticle Traps — •Amin Hosseinkhani[1,2] and Ginaluigi Catelani[1] — [1]Peter Grunberg Institut (PGI-2), Forschungszentrum Jülich, Jülich, Germany — [2]JARA-Institute for Quantum Information, RWTH Aachen University, Aachen, Germany

In many superconducting devices, including qubits, quasiparticle excitations are detrimental. A normal metal (N) in contact with a superconductor (S) can trap these excitations. However, the contact between N and S modifies the properties of both materials, a phenomenon known as proximity effect which has drawn attention since the '60s. Despite this long history, we find new analytical results for the density of states, which shows a square root threshold behavior at the minigap energy. In superconducting qubits, the trap must be placed far enough from a Josephson junction in order not to harm the qubit coherence. To estimate the minimum trap-junction separation, we study how the density of states in the superconductor depends on the distance from the trap. For high interface resistance between N and S, a separation of several (5-7) coherence lengths is sufficient.

15 min. break.

MA 18.8 Tue 11:30 HSZ 103

Generating Entangled Quantum Microwaves in a Josephson-Photonics Device — •Simon Dambach, Björn Kubala, and Joachim Ankerhold — Institute for Complex Quantum Systems, Ulm University, Ulm, Germany

The realization of efficient sources for entangled microwave photons is of paramount importance for many promising applications of quantum technology. In this talk, we demonstrate that Josephson-photonics devices are logical candidates for this task since they allow to create a broad range of different bi- and multipartite entangled states in a surprisingly simple way [1].

In a Josephson-photonics device, a Cooper pair tunneling across a dc voltage-biased Josephson junction simultaneously creates photons in several series-connected microwave cavities. The interplay of this multiphoton creation process and subsequent individual photon leakage from the cavities leads to a stationary state with complex entanglement properties. Sophisticated pulse-shaping schemes as required in conventional circuit-QED architectures are thus not necessary here. Varying experimental parameters in situ or by construction then allows to access the rich wealth of entangled states differing, e.g., in the number of entangled parties or the dimension of state space. Such devices, besides their promising potential to act as a highly versatile source of entangled quantum microwaves, may be also an excellent playground for the abstract branch of quantum information theory to test entanglement criteria on naturally existing quantum states.
[1] S. Dambach, B. Kubala, and J. Ankerhold, arXiv:1609.08990

MA 18.9 Tue 11:45 HSZ 103

Theory of mode locking in pulsed semiconductor quantum dots — •Wouter Beugeling, Götz S. Uhrig, and Frithjof B. Anders — Lehrstuhl für Theoretische Physik 1/2, TU Dortmund, Dortmund, Germany

Electron spins in semiconductor quantum dots appear unsuitable for quantum computing at first sight, due to their fast decoherence caused by hyperfine interactions to the nuclear spins in the substrate. However, the coherence time is dramatically increased by periodic optical pulsing. The underlying mechanism is known as mode locking: Oscillation frequencies incommensurate with the pulse repetition rate are suppressed, and only resonant contributions remain. Because the resonant frequencies are set by the pulse repetition rate only, the system becomes effectively immune to perturbations induced by the hyperfine interactions and by variations between the individual quantum dots in an ensemble.

In this presentation, we explore the mechanism of mode locking with a combination of analytical and numerical methods. Exploiting the fact that the hyperfine interaction is small compared to the external magnetic field, we calculate the dynamics perturbatively. The resulting frequency distributions show clear signs of mode locking. We study the positions of the resonant frequencies and the rate at which mode locking sets in, and compare the results to other theoretical and experimental studies. We also discuss the influence of the hyperfine coupling strength, of the Zeeman effect of the nuclear spins, and of the pulse shape and detuning.

MA 18.10 Tue 12:00 HSZ 103

Higher Order Spin Correlation in Semi-Conductor Quantum Dots — •Nina Fröhling and Frithjof Anders — Technische Universität Dortmund, Deutschland

We study higher order auto-correlation functions of electron spin decay in an isolated semi-conductor quantum dot described by the central spin model. The electronic central spin is coupled to a bath of nuclear spins via hyperfine interaction, which dominates the short time regime. Via quantum measurement theory we show that the experiment by Bechtold et al. (Phys. Rev. Lett. 117. 027402, 2016) can be described as a fourth order auto-correlation function. We compare our results obtained from a semiclassical approach, exact diagonalization and a Lanczos algorithm to the experimental results. In order to explain the observed long time dynamics in the forth order autocorrelation the nuclear Zeeman splitting and the strain induced anisotropic quadrupolar moment of the nuclei must be included.

MA 18.11 Tue 12:15 HSZ 103

Non-equilibrium nuclear spin distributions in a periodically pulsed quantum dot — •Natalie Jäschke and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

In pump-probe experiments single electron charged semiconductor quantum dots are subjected to periodic optical excitations. This mechanism generates electron and nuclear spin polarization. In the short time regime the decoherence of the electron spin polarization is governed by the hyperfine interaction with the nuclear spins. We aim for a theory that combines the effect of the periodic laser pump pulses and the nuclear spin bath on the electron spin polarization. Since the laser pulses occur on the shortest time scale of the system, and the electronic decay times are small compared to those of the nuclear spin bath, we treat the laser pumping quantum-mechanically using a Lindblad approach and keep the nuclear spins as frozen during that time. Then a classical simulation of the Overhauser field bridges the time until the next laser pulse. On the one hand we analyze the time dependence of the electron spin dynamics and on the other hand present data for the non-equilibrium steady state spectral distributions of the Overhauser field for the long time limit. For the electron spin dynamics a revival effect right before the next pulse is observed. The Overhauser field shows mode locking effects in the component parallel to the external magnetic field.

MA 18.12 Tue 12:30 HSZ 103

Detection of coherent oscillations in proximitized quantum dot spin valves — Philipp Stegmann, Jürgen König, and •Stephan Weiss — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

Spin coherent oscillations in a proximitized quantum dot spin valve are resolved by means of full counting statistics of electrons [1]. Especially, generalized factorial cumulants [2,3] of the electronic distribution function are suitable for the detection of the transition between different spin states in the system. We furthermore study the influence of a tunnel coupled superconductor. Due to the presence of Andreev reflections, coherent oscillations between different spin states are modified, the Larmor frequency is renormalized. We explore that general factorial cumulants are able to distinguish different fundamental transport processes of the model [1].

[1] Ph. Stegmann, J. König, S. Weiss, submitted (2016)
[2] Ph. Stegmann, J. König, Phys. Rev. B **92**, 155413 (2015)
[3] Ph. Stegmann, J. König, Phys. Rev. B **94**, 125433 (2016)

MA 18.13 Tue 12:45 HSZ 103

Apparent pairing and subperiods in integer quantum Hall interferometers — •Giovanni Andrea Frigeri[1,3], Daniel Scherer[2], and Bernd Rosenow[3] — [1]Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany — [2]Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark — [3]Institut für Theoretische Physik, Universität Leipzig, Leipzig, Germany

We analyze the magnetic field and gate voltage dependence of the conductance in an integer quantum Hall Fabry-Pérot interferometer, taking into account the interactions between an interfering edge mode, a non-interfering edge mode and the bulk. For weak bulk-edge coupling and sufficiently strong inter-edge interaction, we observe that the interferometer operates in the Aharonov-Bohm regime with a flux periodicity halved respect to the usual expectation. Even in the regime of strong bulk-edge coupling, this behavior can be observed as a subperiodicity of the interference signal in the Coulomb dominated regime. We do not find evidence for a connection between a reduced flux period and electron pairing, though. Our results can reproduce recent experimental findings.

MA 18.14 Tue 13:00 HSZ 103

Interplay of Hamiltonian control and and decoherence: a caveat, some hope and a new simulation strategy — •Jürgen Stockburger — Institute for Complex Quantum Systems, Ulm University

Hamiltonian control and decoherence are intricately intertwined in low-temperature quantum systems. For controls which act on timescales shorter than the thermal time $\hbar\beta$, Markovianity can no longer be assumed (RWA breakdown) [1]. When open-system dynamics is mapped on a stochastic propagation, this case can be treated exactly, and standard optimal control techniques can be used to explore synergy effects between control and reservoir interaction. Quantum states can thus be purified [2] and systems entangled [3] by the combined effect of local control and dissipation.

This stochastic mapping can now be combined with non-perturbative projection techniques, requiring only moderate computational resources [4].

[1] Alicki, R., Lidar, D. A. and Zanardi, P., Phys. Rev. A **73**, 052311 (2006)
[2] Schmidt, R. *et al.*, Phys. Rev. Lett. **107**, 130404 (2011)
[3] Schmidt, R., Stockburger, J. T. and Ankerhold, J., Phys. Rev. A **88**, 052321 (2013)
[4] Stockburger, J. T., EPL (Europhysics Letters) **115**, 40010 (2016)

MA 19: Transport: Topological Semimetals 1 (jointly with DS, MA, HL, O)

Time: Tuesday 9:30–11:45 Location: HSZ 201

MA 19.1 Tue 9:30 HSZ 201

Electron-hole pairing of Fermi arc surface states in a Weyl semimetal bilayer — •Paolo Michetti and Carsten Timm — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

The topological nature of Weyl semimetals (WSMs) is corroborated by the presence of chiral surface states at the boundaries, connecting the bulk Fermi surface by Fermi arcs (FAs). We develop an analysis of the electron-hole pairing instability between the surface states of a bilayer structure realized by introducing a thin insulating spacer into a bulk WSM. We employ a minimal WSM model for the description of the surface states and a self-consistent mean-field treatment of the pairing interaction. We find that the system is unstable towards the formation of coherent electron-hole pairs, which leads to partial gapping of the FA dispersion curve and possibly to a superfluid dipolar exciton condensate, where dissipationless counter-propagating currents can be induced in the two layers. A signature of such condensate is the modifications of the peculiar quantum oscillations from surface FAs. We characterize the dependence of the single-particle energy gap and the critical temperature on the model parameters, where we emphasize in particular the linear scaling of these quantities with the separation between the Weyl points. A detrimental role is played by the curvature of the FA, although the phenomenon persists for moderately low curvature.

MA 19.2 Tue 9:45 HSZ 201

Universality and stability of the edge states of chiral nodal topological semimetals; Luttinger model for $j = \frac{3}{2}$ electrons as a 3D topological semimetal — •Maxim Kharitonov, Julian-Benedikt Mayer, and Ewelina Hankiewicz — Institute for Theoretical Physics and Astrophysics, Wuerzburg University

We theoretically demonstrate that the chiral structure of the nodes of nodal semimetals is responsible for the existence and universal local properties of the edge states in the vicinity of the nodes. We perform a general analysis of the edge states for an isolated node of a 2D semimetal, protected by *chiral symmetry* and characterized by the topological winding number N. We derive the asymptotic chiral-symmetric boundary conditions and find that there are $N+1$ universal classes of them. The class determines the numbers of flat-band edge states on either side off the node in the 1D edge spectrum and the winding number N gives the *total* number of edge states. We then show that the edge states of chiral nodal semimetals are *robust*: they persist in a finite-size *stability region* of parameters of chiral-asymmetric terms. This significantly extends the notion of 2D and 3D topological nodal semimetals. We demonstrate that the Luttinger model with a quadratic node for $j = \frac{3}{2}$ electrons is a 3D topological semimetal in this new sense and predict that α-Sn, HgTe, and possibly $Pr_2Ir_2O_7$, as well as many other semimetals described by it are topological and exhibit surface states.

MA 19.3 Tue 10:00 HSZ 201

Interband optical conductivity of the Dirac semimetal Cd_3As_2 — •D. Neubauer[1], J. P. Carbotte[2], A. A. Nateprov[3], A. Löhle[1], M. Dressel[1], and A. V. Pronin[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Department of Physics and Astronomy, McMaster University, Canada — [3]Institute of Applied Physics, Academy of Sciences of Moldova, Chisinau, Moldova

We measured the optical reflectivity of [001]-oriented n-doped Cd_3As_2 in a broad frequency range (50 – 22 000 cm^{-1}) for temperatures from 10 to 300 K. The optical conductivity, $\sigma(\omega) = \sigma_1(\omega) + i\sigma_2(\omega)$, is isotropic within the (001) plane; its real part follows a power law, $\sigma_1(\omega) \propto \omega^{1.65}$, in a large interval from 2000 to 8000 cm^{-1}. This behavior is caused by interband transitions between two bands, which are effectively described by a sublinear dispersion relation, $E(k) \propto |k|^{0.6}$. The momentum-averaged Fermi velocity of the carriers in these bands is energy dependent and ranges from 1.2×10^5 to 3×10^5 m/s, depending on the distance from the Dirac points. These values are in agreement with the published data on Cd_3As_2. We detect a gaplike feature in $\sigma_1(\omega)$ and associate it with the Fermi level positioned around 100 meV above the Dirac points. Finally, we compare our results with recent magneto-optical infrared data.

MA 19.4 Tue 10:15 HSZ 201

Angular-dependent magnetoresistance of 3D Dirac materials — •Henry Legg and Achim Rosch — Institute for Theoretical Physics University of Cologne Zülpicher Straße 77 D-50937 Köln Deutschland

The realisation of 3D Dirac and Weyl semi-metals has created a new playground for transport phenomena, such as the possibility to produce the chiral anomaly in a condensed matter setting. Many materials that realise a 3D Dirac dispersion are protected by crystal symmetry and therefore have multiple Dirac cones within their Brillouin zone; examples include Cd_2As_2, Na_3Bi, and $Pb_{1-x}Sn_xSe$.

In this work we show that the application of a parallel magnetic and electric field in a direction perpendicular to that connecting a pair of Dirac cones can lead to a large positive magnetoresistance. The magnetic field leaves only an effective one-dimensional dispersion parallel to the field, due to the formation of Landau levels perpendicular to the magnetic field. The result is a large inter-nodal scattering matrix between the two Dirac cones since the Dirac nodes are close in the dimensionally reduced system. Our results are compared to recent experiments on $Pb_{1-x}Sn_xSe$.

15 min. break.

MA 19.5 Tue 10:45 HSZ 201

Quantum oscillation and Dirac fermion in $BaZnBi_2$ system — •Kan Zhao and Philipp Gegenwart — Experimentalphysik VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86159 Augsburg, Germany

Dirac semimetals represent new quantum states of matter and have stimulated intensive studies. $AMnBi_2$(A = alkali earth/rare earth metal) is one of the established Dirac semimetals, with both antiferromagnetic order in $MnBi_4$ layer and Dirac fermion in Bi square net layer.

To investigate how the magnetism interacts with Dirac fermions, we synthesized single crystals of $SrZnBi_2$ and $BaZnBi_2$. Being isostructural to $SrMnBi_2$, $SrZnBi_2$ shows no quantum oscillation in resistivity and magnetic susceptibility up to 14 T. However, $BaZnBi_2$ shows clear multiple quantum oscillations down to 4 T in magnetic susceptibility. According to the temperature dependence of the oscillation amplitude after fast Fourier transformation (FFT), the effective electron mass is about 0.1me, comparable with that of $BaMnBi_2$. In the resistivity measurement up to 14 T at 2 K clear SdH oscillations with main oscillation frequency 168T are observed. The frequency follows a $1/|\cos(\theta)|$ dependence (θ is the angle between magnetic field and c axis), indicating a quasi 2D Fermi surface. Band-structure calculations by I. Mazin, indicate that $BaZnBi_2$ exhibits a unique structure feature and electronic structure, with a quasi Dirac band near the Fermi level. ARPES and high-field SdH measurements, to further characterize the Dirac fermions, are in progress.

MA 19.6 Tue 11:00 HSZ 201

Observation of Topological Surface States and Strong Electron/hole Imbalance in an Extreme Magnetoresistance Semimetal — •Niels Bernhard Michael Schröter[1], Juan Jiang[1,2,3,4], Shu-Chun Wu[5], Nitesh Kumar[5], Chandra Shekhar[5], Han Peng[1], Xiang Xu[6], Cheng Chen[1], Haifung Yang[7], Chan Hwang[4], Sung-Kwan Mo[3], Zhongkai Liu[2], Lexiang Yang[6], Claudia Felser[5], Binghai Yan[5], and Yulin Chen[1,2,6] — [1]University of Oxford, Oxford, UK — [2]ShanghaiTech University, Shanghai, P. R. China — [3]Advanced Light Source, Berkeley, USA — [4]Pohang Accelerator Laboratory, POSTECH, Pohang, Korea — [5]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [6]Tsinghua University, Beijing, P. R. China — [7]Chinese Academy of Sciences, Shanghai, P. R. China

The discovery of an extreme magnetoresistance (XMR) in the non-magnetic rare-earth monopnictides LaX (X = P, As, Sb, Bi), a recently proposed new topological semimetal family, has inspired intensive research on the correlation between the XMR and their electronic structures. In this work, using ARPES to investigate the three dimensional band structure of a lanthanum monopnictide, we unraveled its topologically non-trivial nature with the observation of multiple topological surface Dirac fermions, as supported by our ab-initio calculations. Furthermore, we observed substantial imbalance between the volumes of electron and hole pockets, which rules out the electron-hole compensation as the primary cause of the XMR, putting strong constraints on future theoretical investigations.

MA 19.7 Tue 11:15 HSZ 201

Topological metal with multiple Dirac cones and nodal line — •Ashis Kumar Nandy[1], Alex Aperis[1], M. Mofazzel Hosen[2], Klauss Dimitri[2], Pablo Maldonado[1], Dariusz Kaczorowski[3], Tomasz Durakiewicz[4], Madhab Neupane[2], and Peter M. Oppeneer[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]Department of Physics, University of Central Florida, Orlando, Florida, USA — [3]Institute of Low Temp. & Structure Research, PAS, Wroclaw, Poland — [4]Condens. Matter and Magnet Science Group, LANL, Los Alamos, USA

The extended class of topological materials includes topological (semi) metals that support non-trivial topological surface states in the form of one-dimensional Dirac lines or Fermi-arcs connecting two Weyl points. Here we study a ternary compound using a combination of systematic theoretical calculations and detailed angle-resolved photoemission spectroscopy (ARPES) measurements. In contrast to other topological materials, our first-principles calculations suggest that the band inversion is $d-p$ type instead of the mostly observed $s-p$ type band inversion. We identify multiple Dirac fermionic states at various binding energies. A Dirac cone is computed at the Γ point about 0.5 eV above the chemical potential. Most importantly, at around 1 eV below the Fermi level our calculations reveal a surface nodal line-like feature passing through the time-reversal invariant point M. Our systematic study suggests a new family of materials for exploring the coexistence and competition of multiple fundamental fermionic quantum states.

MA 19.8 Tue 11:30 HSZ 201

***PT* Anomalous Transport in a Nodal Line Dirac Semimetal** — •Wenbin Rui, Yuxin Zhao, and Andreas P. Schnyder — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

Recently PT invariant topological nodal line Dirac semimetals have attracted increasing attentions in quantum matter. Here we study the anomalous transport of the PT symmetric Dirac semimetals of (3+1) dimensions as responses to electromagnetic fields, for which the universal currents are originated from the parity anomaly in (2+1)-dimensional quantum field theory. Considering that the total sum of anomalous currents from soft modes spreading along the nodal loop vanishes, we design a feasible experiment to detect the effect, which is able to separate anomalous currents from distinct regions of the nodal loop.

MA 20: Bio- and Molecular Magnetism

Time: Tuesday 9:30–13:00 Location: HSZ 301

MA 20.1 Tue 9:30 HSZ 301

Changing the Molecular Conformation of Endohedral Rare Earth Single-Molecule Magnets with Magnetic Torque — •Aram Kostanyan[1], Rasmus Westerström[2], Yang Zhang[3], Alexey Popov[3], and Thomas Greber[1] — [1]Physik-Institut, Uni Zürich, Winterthurerstr. 190,8057 Zürich, Switzerland — [2]Division of Synchrotron Radiation Research, Department of Physics, Lund University, Lund, Sweden — [3]Nanoscale Chemistry, IFW Dresden,Helmholtzstr. 20, 01069, Dresden, Germany

The endohedral unit of endohedral fullerenes exhibits thermally activated hopping motion between low-energy conformations. The motion ceases out at low temperatures locking the unit in a random state.

For single-molecule magnet $HoLu_2N@C_{80}$, the magnetic moment of Ho is aligned with the Ho-N axis due to strong ligand field imposed by the N^{3-} ion. If the external magnetic field applies a torque on the magnetic moment of the Ho^{3+} ion it can be transferred to the encapsulated unit.

Field and temperature dependent measurements show a conformational change by means of magnetic torque on a single magnetic moment. At 1.8 K, the in-field cooled sample shows a magnetization curve that exceeds that of the zero-field cooled one. The difference does not scale with a single factor and increases with decreasing temperature sweep rate.

By means of a first order kinetics model, it is possible to determine the attempt frequency and activation energy for the hopping motion. It also allows to understand the non-linear field dependence of the effect.

MA 20.2 Tue 9:45 HSZ 301

High-frequency electron paramagnetic resonance investigation of transition metal complexes – Ni monomer and Ni_2 dimer complexes as single-molecule magnets — •Sven Spachmann[1], Changhyun Koo[1], Msia Tavhelidse[1], Cebrail Pür[1], Roland Bischoff[2], Manuel Reh[2], Hans-Jörg Krüger[2], and Rüdiger Klingeler[1,3] — [1]Kirchhoff Institute for Physics, Heidelberg University, Heidelberg, Germany — [2]Faculty of Chemistry, TU Kaiserslautern, Kaiserslautern, Germany — [3]Center for Advanced Materials, Heidelberg University, Heidelberg, Germany

The magnetic properties of a Ni(II) monomer and a $Ni(II)_2$ dimer with a negatively charged radical bridge ligand are studied by means of high-frequency electron paramagnetic resonance (HF-EPR). The g-factors and the spin ground states of both complexes are unambiguously determined from the spectra: $g = 2.126$, $S = 5/2$ for the dimer, and $g = 2.115$, $S = 1$ for the monomer. Significant zero-field splitting and equally separated resonance features in the EPR spectra indicate the magnetic anisotropy of both complexes. Modelling the experimental data by an appropriate spin Hamiltonian reveals an axial-type anisotropy $|D| = 0.85$ K for the dimer and a plane-type anisotropy $|D| = 4.52$ K for the monomer. The results are compared to similar Ni_2 dimer complexes and the contributions of the different radical bridge ligands to the magnetic anisotropy are discussed.

MA 20.3 Tue 10:00 HSZ 301

Switching of a spin-crossover molecule on a surface — •Torben Jasper-Tönnies[1], Sujoy Karan[1], Hanne Jacob[2], Felix Tuczek[2], and Richard Berndt[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24098 Kiel — [2]Institut für Anorganische Chemie, Christian-Albrechts-Universität zu Kiel, 24098 Kiel

Spin-crossover (SCO) complexes contain a transition metal ion that can be switched between a low-spin and a high-spin state by external stimuli. An adsorbed SCO complex couples to the substrate and consequently may change its spin-switching property. Using low temperature scanning tunneling microscopy we investigated the SCO-compound $[Fe(pap)_2]^+ClO_4^-$ (pap= N-2-pyridylmethylidene-2-hydroxyphenylaminato) on substrates with supposedly different couplings to the molecule, namely Au(111), Cu(001) and Cu2N/Cu(001). Although we made various attempts, we found no indication of any STM tip induced modifications of $Fe(pap)_2$ on Au and Cu. By contrast, single $Fe(pap)_2$ on Cu_2N can be reproducibly and reversibly switched. We observed three states that exhibit different shapes in images and different spectroscopic features. We discuss the data in terms of conformational changes as well as spin-state modifications. Financial support by the SFB 677 is gratefully acknowledged.

MA 20.4 Tue 10:15 HSZ 301

High-frequency EPR study on the $3d$-$4f$ heterometallic single crystal $DyNi_2$ — •Changhyun Koo[1], Msia Tavhelidse[1], Michael Grosshauser[2], Dennis Müller[2], Peter Comba[2], and Rüdiger Klingeler[1,3] — [1]Kirchhoff Institute of Physics, Heidelberg University, Germany. — [2]Institute of Inorganic Chemistry, Heidelberg University, Germany. — [3]Center for Advanced Materials, Heidelberg University, Germany.

$3d$-$4f$ heterometallic complexes provide a potential route to highly anisotropic single molecular magnets with high magnetic moments. Here, we report on the static and dynanmic magnetic properties of a heterometallic $[Dy^{III}(Ni^{II}(L^{tacn}))_2]ClO_4$ (i.e., $DyNi_2$) single crystal. The spin ground state is derived from the static magnetisation data. Due to misaligned magnetic axes of the magnetic ions and twisted misaligned two molecules in the unit cell, our high-frequency electron paramagnetic resonance (HF-EPR) spectra exhibit non-equally separated resonance features including a forbidden transition in a resonance frequency-magnetic field diagram. From the temperature dependence of the resonances, the ground state transitions and the excited state transitions are sorted out. The comparison of experimental data with simulations by means of matrix diagonalization of an appropriate spin Hamiltonian including an Ising concept for the Dy ion allows reasonably estimating the relevant parameters, i.e. D, E, of the Ni ions, and $J_{\mathrm{Dy-Ni}}$ in the $DyNi_2$ complex.

MA 20.5 Tue 10:30 HSZ 301

Magnetic properties of free transition-metal-benzene complexes — •Christine Bülow[1,2], Vicente Zamudio-Bayer[1,3], Rebecka Lindblad[1,4], Martin Timm[1], Akira Terasaki[5], Bernd von Issendorff[3], and Tobias Lau[1] — [1]Helmholtz-Zentrum Berlin, Berlin, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Universität Freiburg, Freiburg, Germany — [4]Lund University, Lund, Sweden — [5]Kyushu University, Fukuoka, Japan

$MnBz_2^+$ (Bz = benzene) is a very stable 18 valence electron system. Theory and indirect experimental evidence indicate either the expected fully quenched or a surprising fully atomic-like spin magnetic moment. For $CrBz_2^+$, which is one electron short of the closed electronic shell, a magnetic moment of either 1 μ_B or 5 μ_B is predicted.
We have investigated the magnetic and electronic properties of $MnBz_n^+$ and $CrBz_n^+$ ($n = 0 - 2$) in the gas phase by x-ray magnetic circular dichroism and x-ray absorption spectroscopy in a cryogenic ion trap. Our results show that 3d electrons in MnBz and CrBz are localized and therefore these complexes carry a magnetic moment whereas in $MnBz_2^+$ and $CrBz_2^+$ the 3d electrons are delocalized and the 3d magnetic moment is quenched.

MA 20.6 Tue 10:45 HSZ 301

Magnetism of highly-ordered two-dimensional arrays of Fe_4 on graphene — •Fabian Paschke[1], Luca Gragnaniello[1], Philipp Erler[1], Peter Schmitt[2], Nicole Barth[1], Sabina Simon[1], Harald Brune[3], Stefano Rusponi[3], and Mikhail Fonin[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Department of Chemistry, University of Konstanz, Germany — [3]Institute of Condensed Matter Physics, École Polytechnique Fédérale de Lausanne, Switzerland

We demonstrate that electrospray deposition enables the fabrication of highly-periodic 2D arrays of Fe_4H single molecule magnets on graphene/Ir(111). From the magnetic field dependence of the x-ray magnetic circular dichroism signal, we infer that the magnetic easy axis of each Fe_4H molecule is oriented perpendicular to the sample surface with the value of the uniaxial anisotropy being unaffected upon the deposition on graphene. Furthermore, we observe inelastic features in STS, due to spin-flip excitations from the magnetic ground state, giving access to the intramolecular exchange coupling J_1 on the single-molecule level, which is unprecedentedly close to the bulk value. Our findings suggest that Fe_4H molecules undergo only negligible interaction with the graphene/Ir(111) substrate, making it possible to build a well-defined two-dimensional system with preserved magnetic properties as compared to bulk.

15 min. break.

MA 20.7 Tue 11:15 HSZ 301

Magnetic properties of EuCot nanowires on graphene/Ir(111) — •Nico Rothenbach[1], Felix Huttmann[2], Katharina Ollefs[1], Stefan Kraus[2], Matthias Bernien[3], Lucas M. Arruda[3], Fabian Nickel[3], Andrew J. Britton[3], Wolfgang Kuch[3], Thomas Michely[2], and Heiko Wende[1] — [1]University of Duisburg-Essen and CENIDE — [2]University of Cologne — [3]Freie Universität Berlin

Magnetic coupling and the magnetic anisotropy of localized 4f magnetic moments connected via organic ligands in molecular networks are a highly topical field of research owing to potential applications in organic spintronics [1-3]. We investigated organometallic sandwich-molecular nanowires of europium-cyclooctatetraene (EuCot) on graphene/Ir(111) by means of x-ray magnetic circular dichroism (XMCD) down to 2.5 K. Using temperature-, angular-, and field-dependent europium $M_{4,5}$-edge XMCD measurements we studied two different coverages, namely 0.5 and 2.0 monolayers (ML) of EuCot. The comparison of the XMCD spectra of the submonolayer EuCot sample with the multilayer sample shows pronounced differences, resulting in different orbital moments. Furthermore, for the submonolayer coverage we determine a clearly different functional behavior of the field-dependent XMCD data for normal and grazing x-ray incidence, whereas no anisotropic behavior is found for the 2.0-ML sample.

[1] P. Gambardella et al., Nature Materials 8, 189 (2009)
[2] A. Lodi Rizzini et al., Surface Science 630, 361 (2014)
[3] Y. Lan et al., J. Mater. Chem. C 3, 9794 (2015)

MA 20.8 Tue 11:30 HSZ 301

Formation of metallofullerene magnetic arrays: theoretical perspectives. — •Stanislav Avdoshenko and Alexey Popov — Institute for Solid State Research, IFW, Dresden

Modeling of formation and properties self-assembled monolayer (SAM) is a very challenging task, especially if highly functional-ligands are concerned. It is true, for instance, in the case of endohedral metallofullerene (EMF) based SAM - promising single molecular magnets (SMMs) grids in-making. Properties of such SMM grids would be a function of SAM architecture (attachment types and crowding effects) and innercluster dynamics under these geometrical constrains. Electronic structure complexity of EMFs and structural mobility of ligands in SAMs brings a dual issue. On the one hand, a minimal level of theory to address the magnetic properties of the systems would require "complete active space"- quality methods. On the other hand, while the system dynamic can be approached by less computationally demanding semiclassical or even classical approaches, such methods are unable to give a reliable magneto-physics of the SMM unit. In our report, we will offer a set of concepts to deal with this problem by extensive development of the multiscale methods (MSM), in which the whole system is divided into the regions described with different levels of theory accordingly to its complexity.

MA 20.9 Tue 11:45 HSZ 301

Recent development of endohedral metallofullerenes for single molecule magnetism — •Alexey Popov[1], Denis Krylov[1], Fupin Liu[1], Lukas Spree[1], Stanislav Avdoshenko[1], Aram Kostanyan[2], and Thomas Greber[2] — [1]Nanoscale Chemistry, Leibniz Institute for Solid State and Materials Research (IFW Dresden),Helmholtzstrasse 20 01069, Dresden, Germany — [2]Physik-Institut, Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

The molecules of endohedral metallofullerenes (EMFs) comprise the fullerene cage encapsulating metal ions (usually lanthanides). Metal atoms donate their valence electrons to the fullerene cage resulting in ionic environment, and Coulomb repulsion between metal atoms can be balanced by a presence of negatively charged non-metals. This results in a large magnetic anisotropy with quasi-uniaxial ligand field, which leads to the single molecule magnet (SMM) behaviour of lanthanide-based EMFs. When more than one lanthanide ion is encapsulated, the intracluster exchange and dipolar interactions have dramatic effect on the magnetic properties.

Here we will discuss the progress in the synthesis and magnetic properties of endohedral metallofullerenes. Different type of endohedral clusters (nitride, carbide, sulfide) as well as dimetallofullerenes will be considered and the influence of central non-metal atoms on magnetic anisotropy of lanthanides and intracluster exchange interaction will be analyzed. The route to EMF-SMMs with high blocking temperatures will be outlined.

MA 20.10 Tue 12:00 HSZ 301

Efficient ab-initio treatment of magnetism in metal organic frameworks — •Kai Trepte[1], Sebastian Schwalbe[2], Jens Kortus[2], and Gotthard Seifert[1] — [1]Technische Universität Dresden, Theoretical Chemistry, Germany — [2]Technische Universität Bergakademie Freiberg, Institute for Theoretical Physics, Germany

Metal organic frameworks (MOFs) contain specific metal centers as a secondary building unit (SBU) which are interconnect via organic linkers to form three-dimensional networks. An example of a magnetic MOFs is DUT-8(Ni) (DUT - Dresden University of Technology), where the SBUs are Ni dimers. Initially, we studied the magnetic ground state of the crystalline system [1], which turns out to be antiferromagnetic. Considering that MOFs tend to have rather large unit cell (> 100 atoms), we generated a set of model systems (< 30 atoms) which are based on the crystalline structures. These models represent the magnetic properties of the crystals while drastically reducing computational time. Additionally, modifications on the models are easy to implement, allowing the study of different chemical environments or other metal centers and the effect on the magnetic coupling [2]. These investigations show that it is possible to introduce a ferromagnetic/high-spin (HS) coupling into the original system.

[1] Trepte et al., PCCP, vol. 17, pp. 17122-17129, 2015

[2] Schwalbe et al., PCCP, vol. 18, pp. 8075-8080, 2016

MA 20.11 Tue 12:15 HSZ 301

Influence of intermolecular interactions on magnetic observables — •Jürgen Schnack — Universität Bielefeld, Fakultät für Physik, Universitätsstr. 25, D-33615 Bielefeld

Very often it is an implied paradigm of molecular magnetism that magnetic molecules in a crystal interact so weakly that measurements of dc magnetic observables reflect ensemble properties of single molecules. But the number of cases where the assumption of virtually noninteracting molecules does not hold grows steadily. A deviation from the noninteracting case can especially clearly be seen in clusters with antiferromagnetic couplings, where steps of the low-temperature magnetization curve are smeared out with increasing intermolecular interaction. In this contribution we demonstrate with examples in one, two, and three space dimensions how intermolecular interactions influence typical magnetic observables such as magnetization, susceptibility, and specific heat.

[1] J. Schnack, Phys. Rev. B **93** (2016) 054421

MA 20.12 Tue 12:30 HSZ 301

Inelastic Neutron Scattering and Mössbauer Spectra of a Novel Spin Frustrated Fe_7-Propeller — •Siyavash Nekuruh[1], K. Prsa[1], I. Kühne[2], C.E. Anson[2], A.K. Powell[2], and O. Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Institut für Anorganische Chemie, Karlsruhe Institut für Technologie (KIT)

Among the series of hepta-nuclear Fe^{III} molecular complexes with disk shape, the molecule $[Fe_7^{III}(Cl)(MeOH)_6O_3(OMe)_6(PhCO_2)_6]Cl_2$, or Fe_7 in short, is exceptional: It exhibits a unique antiferromagnetic exchange topology, which is reminiscent of a three-bladed propeller, giving rise to spin frustration.

We here present a study of the magnetic excitations in Fe_7 by inelastic neutron scattering (INS), and Mössbauer spectroscopy. The INS spectra exhibit three features at energies of 0.27, 0.57 and 1 meV, which from T and Q dependence are of magnetic origin. Field dependent Mössbauer spectra could be fitted to two well defined and distinct sextets, one of the sextets was assigned to the central Fe ion and the other to the six peripheral Fe ions. The Mössbauer data allow us to extract the respective local Fe spin densities, providing additional insight in the spin frustration in the molecule.

MA 20.13 Tue 12:45 HSZ 301

Polarized inelastic neutron scattering study of a single-molecule magnet Mn_5 — •Krunoslav Prsa[1], Hui-Lien Tsai[2], Hannu Mutka[3], Pascale Deen[4], and Oliver Waldmann[1] — [1]Physikalisches Institut Universität Freiburg, Germany — [2]Department of Chemistry, National Cheng Kung University, Tainan, Taiwan — [3]Institut Laue Langevin, 6 Rue Jules Horowitz, B.P. 156, 38042 Grenoble, Cedex 9, France — [4]European Spallation Source, Tunavagen 24, 223 63 Lund, Sweden

The polarized inelastic neutron scattering technique extends the usual non-polarized variety by being able to discern between the vibrational and magnetic signals. We show results of inelastic neutron scattering study on a coventional 3*d*-element single-molecule magnet Mn_5 [1]. The non-polarized data taken at the IN5 spectrometer reveal five peaks with additional broader features in the spectrum: I at 0.38 meV, II at 0.55 meV, III at 1.9 meV and IV at 3.8 meV and V at 7.7 meV. Based on the temperature dependence, the peak I is clearly a cold magnetic peak, while for the other peaks the assignment was less obvious. A subsequent polarized experiment at the D7 spectrometer directly proved the magnetic origin of the peak III. In addition, the polarization analysis of the elastic channel enabled extraction of the pure nuclear scattering that confirmed the persistence of the crystal structure upon cooldown. Together with the published thermodynamical data [1], these results have allowed us to determine the parameters of the microscopic Hamiltonian of the system.

[1] C-I. Yang *et. al.*, JACS 456-457 (**129**), 2007.

MA 21: Correlated Electrons: Frustrated Magnets - Strong Spin-Orbit Coupling 1

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

MA 21.1 Tue 9:30 HSZ 304

Quantum spin liquid ground state in $Ba_3InIr_2O_9$: A combined NMR and μSR study — •Mayukh Majumder[1], Tusharkanti Dey[1], Jean-Christophe Orain[2], Norbert Buettgen[3], Alexander Tsirlin[1], and Philipp Gegenwart[1] — [1]EP-VI, EKM, University of Augsburg, Germany — [2]Paul Scherrer Institute, Switzerland — [3]EP-V, EKM, University of Augsburg, Germany

5*d* Iridium based systems have drawn a lot of attention because of the presence of similar energy scales of crystal field splitting, spin-orbit coupling and on-site Coulomb interaction which give rise to unconventional ground states. In the present compound $Ba_3InIr_2O_9$ (Ir has an average of +4.5 oxidation state), Ir-dimers aligned along crystallographic c-axis form a triangular lattice which promotes frustration. The magnetization and specific heat show no evidence of long-range magnetic ordering down to 400 mK. We have employed ^{115}In (I=9/2) NMR and μSR to study the microscopic nature of the ground state. ^{115}In Knight shift and line width exhibit a temperature independent behavior below 1.4 K down to 25 mK which indicates no static correlations are developing down to such a low temperature whereas the nuclear spin-lattice relaxation rate $(1/T_1)$ shows a dynamical behavior in the same temperature range and follows a $T^{2.2}$ power law. Furthermore, we have carried out μSR experiments which also discarded the presence of any static long-range ordering and provide the evidence of dynamical fluctuations down to 25 mK. Altogether, local probes provide strong evidence for gapless quantum spin liquid ground state in $Ba_3InIr_2O_9$.

MA 21.2 Tue 9:45 HSZ 304

Spin liquid behavior in the triangular lattice iridate $Ba_3InIr_2O_9$ — •Tusharkanti Dey[1], Mayukh Majumder[1], Anatoliy Senyshyn[2], Panchanan Khuntia[3], Alexander Tsirlin[1], and Philipp Gegenwart[1] — [1]EP-VI, EKM, University of Augsburg, Germany — [2]Munich University of Technology, Germany — [3]Universite Paris-Sud, Orsay, France

Materials with the general formula $Ba_3MIr_2O_9$ (M is a trivalent ion) crystallize in a hexagonal structure containing face-sharing Ir_2O_9 bioctahedra forming Ir-Ir dimers along the crystallographic c-axis. These dimers build a triangular lattice in the crystallographic ab-plane. In these materials, Ir has a single crystallographic site with an average charge state +4.5. Therefore the two Ir sites within the dimer share one electron among them. This fractional charge state combined with the frustrated geometry give rise to many interesting properties like magnetoelastic effect, spin gap behavior and magnetic ordering. We have recently synthesized polycrystalline sample of $Ba_3In^{3+}Ir^{4.5+}{}_2O_9$ and studied its structural, magnetic and thermodynamic properties in detail. Our magnetic susceptibility data show the absence of magnetic ordering down to 0.4 K which is very small compared to the Weiss temperature. The magnetic heat capacity shows a hump at 1.6 K and follows power law with temperature below 1 K. In this presentation, we will discuss these results suggesting a quantum spin liquid ground state for this material.

MA 21.3 Tue 10:00 HSZ 304

Magnetism of honeycomb ruthenate $Ag_3LiRu_2O_6$ without singlet dimers — •Tomohiro Takayama[1,2] and Hidenori Takagi[1,2,3] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]FMQ3, University of Stuttgart, Stuttgart, Germany — [3]Department of Physics, University of Tokyo, Tokyo, Japan

Honeycomb-based transition-metal oxides currently attract interests as novel quantum magnets. 5*d* honeycomb iridates were theoretically proposed to host quantum spin liquid state owing to bond-dependent magnetic coupling (Kitaev coupling)[1], and experimental verifications of such spin liquid state are intensively under way. On the other hand, honeycomb ruthenate Li_2RuO_3 is known to form spin-singlet dimers and the ground state is non-magnetic insulator [2].

By using ion-exchange reaction, we have synthesized silver-intercalated honeycomb ruthenate $Ag_3LiRu_2O_6$ [3]. Possibly due to the formation of strong O^{2-}-Ag^+-O^{2-} between the honeycomb layers, the singlet-dimer formation is suppressed in $Ag_3LiRu_2O_6$, and Ru^{4+}

magnetism survives down to low temperatures. Despite Curie-Weiss like behavior observed at high temperatures (θ_{CW} ∼ -40 K), we did not see any magnetic order down to 2 K in magnetization and heat capacity measurements. We discuss the possible magnetic ground state of this honeycomb ruthenate.

[1] G. Jackeli and G. Khaliullin, Phys. Rev. Lett. 102, 017205 (2009)
[2] Y. Miura et al., J. Phys. Soc. Jpn., 76, 033705 (2007)
[3] S. Kimber et al., J. Mater. Chem. 20, 8021 (2010)

MA 21.4 Tue 10:15 HSZ 304

Long-range interactions in the effective low energy Hamiltonian of Sr_2IrO_4: a core level resonant inelastic x-ray scattering — •Stefano Agrestini[1], Chang-Yang Kuo[1], Marco Moretti Sala[2], Zhiwei Hu[1], Deepa Kasinathan[1], Pieter Glatzel[2], Tomohiro Takayama[3,4], Hidenori Takagi[3,4,5], Liu Hao Tjeng[1], and Maurits W. Haverkort[1,6] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]ESRF, Grenoble, France — [3]Department of Physics and Department of Advanced Materials, University of Tokyo, Japan — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany — [5]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Germany — [6]Institute for theoretical physics, Heidelberg University, Germany

The iridates have received tremendous attention due to the high expectations of finding new exotic phenomena and the long-sought materialization of the Kitaev model. Experimentally, however, most compounds order magnetically. Here we address the puzzle of the ground state in iridates by measuring core-to-core resonant inelastic x-ray spectroscopy on Sr_2IrO_4. From the spectra analysis we found that Sr_2IrO_4 is highly covalent with the effective t_{2g} orbitals very extended spatially. They are not the standard orbitals with nearest-neighbor-only magnetic interactions that most people have in mind. We thus explain why compass models are not realized in most studied iridates and we show a pathway how one can achieve the Kitaev model using other crystal structures or transition metal ions.

MA 21.5 Tue 10:30 HSZ 304

Differences in motion of a single hole and a single electron in the quasi-2D iridates — •Ekaterina Paerschke[1], Krzysztof Wohlfeld[2], Kateryna Foyevtsova[3], and Jeroen van den Brink[1] — [1]IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Pasteura 5, PL-02093 Warsaw, Poland — [3]University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1 Canada

We study the motion of a single charge (hole or electron) added to the (Mott) insulating and antiferromagnetically ordered ground state of the quasi-2D iridates, such as Ba_2IrO_4 or Sr_2IrO_4. Using the self-consistent Born approximation applied to the appropriate strong coupling model we show the intrinsic and qualitative differences between the hole and electron cases. On one hand, the added electron forms a spin polaron, which qualitatively resembles the well-known case of the quasi-2D cuprates doped with a single hole or electron. On the other hand, the case with the added hole is far more complex, due to the formation of the $5d^4$ configuration which may carry finite angular momentum J: here the well-known spin polaronic physics is modified due to the additional degrees of freedom and the possibility of the free hole motion between the different AF sublattices. These results have important consequences not only for the photoemission experiments of the undoped quasi-2D iridates but also suggest that the physics of the electron- and hole-doped iridates is fundamentally different.

MA 21.6 Tue 10:45 HSZ 304

Electronic structure of Sr_2IrO_4 probed with low temperature scanning tunneling microscopy — Zhixiang Sun, •Jose M. Guevara, Danny Baumann, Kaustuv Manna, Sabine Wurmehl, Bernd Büchner, and Christian Hess — IFW-Dresden, Helmholtzstrasse 20, 01069

Sr_2IrO_4 is the main example of a spin-orbit assisted Mott insulator. In the family of iridates, Sr_2IrO_4 has also been postulated as a candidate to emulate the physics of the parent compound of the high-temperature superconductors cuprates, where the doping effect in the insulator to metal transition is still not well understood.

In this work, we classify different predominant defects in Sr_2IrO_4, with low temperature STM/S. We probe the spatial structure symmetry of these defects. From the tunneling spectra, we identify the energy of the upper and lower $J_{eff} = 1/2$ Hubbard bands, the Mott gap, and the variation of the electronic structure due to defects. A charge transfer-like behavior for the defect caused ingap states is observed.

Our measurements provide detailed results about the defect effects to the electronic properties of Sr_2IrO_4, which can be important for further understanding of the doping effect in iridates and the insulator to metal transition in Mott insulators.

MA 21.7 Tue 11:00 HSZ 304

New pyrochlore iridate $In_2Ir_2O_7$ stabilised by high pressure — •Aleksandra Krajewska[1,2], Tomohiro Takayama[1,2], Robert Dinnebier[2], Alexander Yaresko[2], Kenji Ishii[3], and Hidenori Takagi[1,2] — [1]Institut für Funktionelle Materie und Quantentechnologien, University of Stuttgart, 70550 Stuttgart, Germany — [2]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [3]QST, Hyogo 679-5148, Japan

In $5d$ transition metal oxides Coulomb repulsion, crystal field splitting and spin-orbit coupling are comparable which leads to a variety of exotic electronic states. Pyrochlore iridates with chemical formula $A_2Ir_2O_7$ (A= Y, rare earth) consist of A and Ir corner-sharing tetrahedral networks and are predicted to exhibit Weyl semimetal or topological insulator states. Their properties depend on the ionic radius of A^{3+}, where the system is driven from metallic to insulating regime with decreasing A^{3+} size. Those effects are likely related to diverging degree of local lattice distortion. In our work in order to explore small A^{3+} limit we synthesised new pyrochlore $In_2Ir_2O_7$ using high pressure. Structural analysis shows its octahedra are the most distorted among $A_2Ir_2O_7$ family which is in agreement with its insulating behaviour. It shows magnetic order at $T_N = 55$ K with $\theta_{CW} \sim$ -400 K, which suggests strong frustration and is in large contrast with $Y_2Ir_2O_7$ (T_N = 155 K, $\theta_{CW} \sim$ -130 K). Our band calculation shows that despite large distortion $In_2Ir_2O_7$ is in proximity to pure $j_{eff} = 1/2$, unlike $Y_2Ir_2O_7$, which shows strong hybridisation of $j_{eff} = 1/2$ and $j_{eff} = 3/2$. We will discuss the possible origin of almost pure $j_{eff} = 1/2$ state in $In_2Ir_2O_7$.

15 min. break.

MA 21.8 Tue 11:30 HSZ 304

Magnetic ground state of the pyrochlore iridate $Nd_2Ir_2O_7$ — •Hanjie Guo[1], Clemens Ritter[2], Kazuyuki Matsuhira[3], Isao Watanabe[4], Liu Hao Tjeng[1], and Alexander Komarek[1] — [1]MPI CPfS, Dresden, Germany — [2]ILL, Grenoble, France — [3]Kyushu Institute of Technology, KitaKyushu, Japan — [4]RIKEN, Wako, Japan

Pyrochlore iridates are of interest due to the interplay between the relatively large spin-orbit coupling and electron-electron correlations which may induce novel phases such as Weyl semimetals. One important task for understanding the properties of these compounds is the determination of the magnetic structure which is challenging due to the small size of Ir^{4+} moments and maybe also due to the neutron absorption from Ir atoms. Our μSR studies on $Nd_2Ir_2O_7$ clearly show two transitions below about 30 and 9 K related to the Ir and Nd sublattices, respectively. The full magnetic structure including the Ir sublattice has been determined by means of powder neutron diffraction at the high flux D20 diffractometer at the ILL. Our magnetic structure refinement unravels a so-called all-in/all-out magnetic structure for both the Nd and the Ir sublattices. The ordered magnetic moments at 1.8 K amount to 0.34(1) μ_B/Ir^{4+} and 1.27(1) μ_B/Nd^{3+}.

[1] H. Guo, C. Ritter and A. C. Komarek, Phys. Rev. B **94**, 161102(R) (2016).

MA 21.9 Tue 11:45 HSZ 304

Synthesis and magnetic properties of double perovskites with Ir(IV)-states — •Michael Vogl[1], Tusharkanti Dey[1,2], Laura Teresa Corredor Bohorquez[1], Saicharan Aswartham[1], Anja Wolter-Giraud[1], Sabine Wurmehl[1], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research , Dresden, Germany — [2]EP-VI, Electronic Correlations and Magnetism, University of Augsburg, Germany

With strong spin-orbit coupling 5d-based iridates exhibit many interesting phenomena and ground states. Here, we synthesized and investigated two series of 5d-based double perovskites $La_2Co_{1-x}Zn_xIrO_6$ and $La_2Cu_{1-x}Zn_xIrO_6$. Polycrystalline samples of the substitution series were synthesized by conventional solid state reaction and characterized by structural, magnetic and specific heat measurements. In both parent compounds (x=0) complex magnetic interactions between the strongly spin-orbit coupled 5d-ion Ir^{4+} and a magnetic 3d-transition metal ion (Co/Cu) are present. Dilution with non-magnetic Zn^{2+} is used to further study this interaction.

The evolution of the magnetic properties throughout both series is discussed. A strong shift of the transition temperatures to lower temperatures can be observed with increasing Zn-content. The magnetic phase diagram for both the series is mapped out.

MA 21.10 Tue 12:00 HSZ 304

Correlating paramagnetic spin centers in the 'nonmagnetic' 5d^4 compound Ba_2YIrO_6 — •Stephan Fuchs[1], Vladislav Kataev[1], Franziska Hammerath[1], Gizem Aslan Cansever[1], Tushar Dey[1], and Bernd Büchner[1,2] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden,D-01171 — [2]Institut für Festkörperphysik, Technische Universität Dresden,D-01062

We will present the electron spin resonance results of the double perovskite Ba_2YIrO_6. This material provides a playground to examine the magnetic interactions in a 5d transition metal oxide with strong spin-orbit coupling. Theory predicts that due to the strong spin-orbit coupling this 5d^4 iridate should be in a nonmagnetic state. However, static magnetic and NMR measurements evidence the occurrence of paramagnetic spin centers that are correlated at low temperatures. To obtain deeper insight into the magnetic properties of Ba_2YIrO_6 ESR measurements of a polycrystalline sample were carried out for several temperatures and frequencies. This enables to quantify several different paramagnetic spin centers. Two of them correspond to S=1/2 with the g-factor g=1.99 and g=1.90, and the third one to S=3/2 with g=1.49. An overview of the possible origins for the different spin centers and their relevance to the unexpected magnetism of this compound will be given in this talk.

MA 21.11 Tue 12:15 HSZ 304

The iridium double perovskites with Ir^{5+} revised: a combined structural and specific heat study — •Mihai I. Sturza[1], Laura T. Corredor[1], Gizem Aslan Cansever[1], Kaustuv Manna[1], Sebastian Gass[1], Tushar Dey[1], Christian Blum[1], Andrey Maljuk[1], Olga Kataeva[2], Sabine Wurmehl[1], Anja Wolter[1], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research IFW, Institute for Solid State Research, 01069 Dresden, Germany — [2]A.E. Arbuzov Institute of Organic and Physical Chemistry, Russian Academy of Sciences, Kazan, Russia

Recently, the iridate double perovskite Sr_2YIrO_6 has attracted considerable attention due to the report of unexpected magnetism in this Ir^{5+} material, in which according to the Jeff model, a non-magnetic ground state is expected. We present a structural, magnetic and thermodynamic characterization of Sr_2YIrO_6 and Ba_2YIrO_6 single crystals, with emphasis on the temperature and magnetic field dependence of the specific heat. In agreement with the expected non-magnetic ground state of Ir^{5+} ($5d^4$) in these iridates, no magnetic transition is observed down to 430 mK. Moreover, our results suggest that the low temperature anomaly observed in the specific heat is not related to the onset of long-range magnetic order. Instead, it is identified as a Schottky anomaly caused by paramagnetic impurities present in the sample, of the order of 0.5(2) %. These impurities lead to non-negligible spin correlations, which nonetheless, are not associated with long-range magnetic ordering.

MA 21.12 Tue 12:30 HSZ 304

Strain induced changes of electronic properties of B–site ordered Sr_2CoIrO_6 thin films — •Sebastian Esser[1], Chun-Fu Chang[2], Vladimir Roddatis[3], Vasily Moshnyaga[4], Liu Hao Tjeng[2], and Philipp Gegenwart[1] — [1]Experimentalphysik VI, Universität Augsburg, 86159 Augsburg, Germany — [2]Max Planck Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany — [3]Institut für Materialphysik, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [4]1. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

Tight-binding calculations for perovskite $SrIrO_3$ indicate a line node near the Fermi energy. Introducing a staggered potential between the iridate layers should gap out the nodal line, leaving a pair of three-dimensional nodal points [1] and providing a strong motivation to synthesize B–site ordered double perovskite iridate materials.

By using a metal-organic aerosol deposition technique we have grown Sr_2CoIrO_6 thin films on various (pseudo) cubic (001)-oriented substrates to investigate the strain induced changes of the electronic properties. The fully epitaxial strained state of the thin films was verified by x-ray diffraction patterns in combination with reciprocal space mapping and TEM images. HAXPES measurements at SPring-8 indicating a strain induced change of the valence band in the near of the Fermi edge. These changes are also affecting the electrical transport properties, which were investigated down to lowest temperatures.

This work is supported by the German Science foundation through SPP 1666.

[1] J.-M. Carter *et al.*, Phys. Rev. B **85** (2012) 115105.

MA 21.13 Tue 12:45 HSZ 304

Frustrated magnetism and Kitaev exchange on the fcc lattice of K_2IrCl_6 — •Nazir Khan and Alexander A. Tsirlin — EP VI, EKM, Augsburg University, 86159 Augsburg, Germany

Face-centered cubic lattice (fcc) is inherently frustrated, whereas Ir^{4+} ion brings the possibility of Kitaev anisotropy. Synchrotron x-ray study on the powder sample of K_2IrCl_6 shows that the compound retains its room temperature fcc structure (space group Fm-$3m$) and symmetrical Cl_6 octahedral environment down to the low temperature of 20 K followed by 3% volume collapse of the unit cell. Temperature and field dependence of magnetization show that the compound undergoes a paramagnetic to an antiferromagnetic phase transition at T_N=3.14 K. The Curie-Weiss fitting to the high temperature data yields an effective magnetic moment μ_{eff} =1.69 μ_B/Ir ion and Curie-Weiss temperature θ_{CW}=−41.0 K. The frustration parameter, $f = |\theta_{CW}|/T_N$, is found to be 13.0 which suggests presence of significant magnetic frustration. The temperature dependence of electrical resistivity shows that the compound is an insulator with a charge gap close to 0.7 eV.

MA 22: Surface Magnetism (Joint Session with O)

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

Invited Talk MA 22.1 Tue 9:30 HSZ 401

Tuning the zero-point spin-fluctuations of single adatoms — •Julen Ibañez-Azpiroz — Peter Grünberg Institut and Institute of Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Single-adatoms deposited on metallic substrates offer an exceptional playground for studying magnetism at the atomic scale and give rise to several intriguing questions. For instance, although several adatoms exhibit a large magnetic anisotropy energy as measured by X-ray Magnetic Circular Dichroism [1], the very same adatoms behave as paramagnetic objects when probed by Scanning Tunneling Spectroscopy (STS) [2, 3]. Motivated by this apparent contradiction, we analyze the role of quantum fluctuations of the adatom's spin at T=0, the so-called zero-point spin-fluctuations (ZPSF) utilizing time-dependent density functional theory [4]. We investigate several 3d and 4d magnetic adatoms on different substrates, accessing the magnitude of ZPSF and identifying the underlying physical mechanism as well as their implication on the magnetic stability. Remarkably, while spin-fluctuations weaken magnetism, they could be used to detect magnetic signals even in non-magnetic adatoms. We show that the latter can exhibit intense paramagnetic spin-excitations easily tunable with a magnetic field and potentially observable with inelastic STS [5].

[1] P. Gambardella etal., Science 300, 1130 (2003). [2] L. Zhou etal., Nat. Phys. 6, 187 (2010). [3] A. A. Khajetoorians, etal., PRL 106, 037205 (2011). [4] J. Ibañez-Azpiroz etal., Nano Lett. (2016), 10.1021/acs.nanolett.6b01344 [5] J. Ibañez-Azpiroz etal., in prep.

15 min. break

MA 22.2 Tue 10:15 HSZ 401

Measurement of a Nano-Skyrmionic lattice via Magnetic Exchange Force Microscopy — •Josef Grenz, Alexander Schwarz, and Roland Wiesendanger — Institute of Nanostructure and Solid State Physics, University of Hamburg, Jungiusstraße 11A, 20355 Hamburg, Germany

Skyrmions are complex spin textures, which occur in crystals without inversion symmetry due to the Dzyaloshinskii-Moriya interaction. Recently, the monolayer of Fe on a Ir(111) surface attracted a lot of interest, because it exhibits an interface induced Skyrmionic state with a lattice constant of 1 nm [1]. Here, we study the Fe/Ir(111) system utilizing magnetic exchange force microscopy (MExFM). This method has been employed previously to investigate antiferromagnetic structures with atomic resolution [2-4]. We demonstrate that MExFM is able to resolve the arrangement of atoms and the spin texture simultaneously on a non-collinear magnetic structure. Such image data allow to straightforwardly identify the (in-) commensurability between atomic and magnetic structure.

[1] S. Heinze, *et al.*, Nature Phys. **7**, 713 (2011).
[2] U. Kaiser, *et al.*, Nature **446**, 522 (2008).
[3] R. Schmidt, *et al.*, Nano Lett. **9**, 200 (2009).
[4] F. Pielmeier, *et al.*, Phys. Rev. Lett. **110**, 266101 (2013).

MA 22.3 Tue 10:30 HSZ 401

Repulsive Skyrmion Interaction observed in Pd/Fe-Nanoislands on Ir(111) — •Philipp Lindner, Johannes Friedlein, Jonas Harm, Stefan Krause, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstraße 11A, 20355 Hamburg, Germany

Recently, the realization of a room temperature skyrmionic racetrack-style memory device was reported [1], opening the path to ultradense data storage and high speed processing applications with magnetic skyrmions as information carriers.

Using spin-polarized scanning tunneling microscopy, controlled writing and deleting of single atomic-scale magnetic skyrmions was demonstrated via local injection of spin-polarized tunnel electrons in the Pd/Fe/Ir(111) system [2]. To design and construct novel spintronic devices, one has to understand and tailor the interaction of skyrmions in close vicinity to each other.

For our study we epitaxially grew Pd nanoislands on the Fe-monolayer on top of Ir(111). For a perpendicular magnetic field above 2 T, an isolated skyrmion phase is observed. We report experimental evidence of a repulsive short range interaction between individual skyrmions, supported by complementary time-resolved and static scanning tunneling microscopy studies. The experimental findings are discussed in terms of displacement, structural changes and lowered stability of the affected skyrmions.

[1] S. Woo et al., Nature Materials 15, 501 (2016).
[2] N. Romming et al., Science 341, 713 (2013).

MA 22.4 Tue 10:45 HSZ 401

Tuning DMI in antiferromagnetic Fe/Ir interfaces — •Sebastian Meyer, Bertrand Dupé, Paolo Ferriani, and Stefan Heinze — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel

Recently, magnetic skyrmions could be stabilized in ultrathin films at surfaces due to the interfacial Dzyaloshinskii-Moriya interaction (DMI) [1,2]. Their intriguing topological and dynamical properties make them interesting for future spintronic applications [3]. It has been predicted that skyrmions in antiferromagnets posses favorable transport properties compared to those in ferromagnets [4]. Here, we present a way to tune the DMI in antiferromagnetic Fe/Ir interfaces. We study Fe/Ir bilayers on Rh(001) using density functional theory as implemented in the FLEUR code (www.flapw.de). For both stackings of the bilayer, i.e. Fe/Ir/Rh(001) and Ir/Fe/Rh(001), the nearest-neighbor (NN) exchange is antiferromagnetic. Fe/Ir/Rh(001) has magnetic properties similar to Fe/Ir(001) [5] and for Ir/Fe/Rh(001), we find very large values of the DMI. Due to exchange frustration, the DMI even exceeds the NN exchange in absolute value. By adding a second Ir overlayer, the DMI is reduced by 60% emphasizing the impact of the Fe/Ir interface on the DMI.

[1] S. Heinze *et al.*, Nature Phys. **7**, 713 (2011).
[2] N. Romming *et al.*, Science **341**, 636 (2013).
[3] A. Fert *et al.*, Nature Nano, **8**, 3 (2013).
[4] J. Barker *et al.*, Phys. Rev. Lett. **116**, 147203 (2016).
[5] M. Hoffmann *et al.*, Phys. Rev. B **92**, 020401 (2015).

MA 22.5 Tue 11:00 HSZ 401

Probing short and long range magnetic interactions on the nanoskyrmion system Fe/Ir(111) with force spectroscopy — •Alexander Schwarz, Josef Grenz, and Roland Wiesendanger — Universität Hamburg, Institut für Nanostruktur- und Festkörperphysik, Jungiusstr. 11, 20355 Hamburg

With a lattice constant of just 1 nm the Fe monolayer on Ir(111) exhibits the smallest skyrmion lattice observed so far [1]. Utilizing magnetic exchange force microscopy (MExFM) [2] we are able to simultaneously resolve the atomic and magnetic structure. Unlike on antiferromagnetic surfaces studied previously with MExFM [2,3], the long range dipolar magnetic force does not cancel out completely above the surface.

To investigate the interplay between chemical, magnetic exchange and magnetic dipolar interactions, we recorded site specific force spectroscopy data. We find that the magnetic lattice can be detected before atomic resolution is achieved, indicating that long-range magnetic dipolar forces contribute significantly to the magnetic signal. This finding suggests that magnetic force microscopy (MFM) imaging of such a nanoskyrmion lattice is feasible. Since MFM is performed at larger tip sample separations than required for MExFM the magnetic structure is less perturbed by the presence of a magnetic tip.

[1] S. Heinze et al., Nature Physics **7**, 713 (2011).
[2] U. Kaiser et al., Nature **446**, 522 (2007).
[3] R. Schmidt et al., Nano Lett. **9**, 200 (2009).

MA 22.6 Tue 11:15 HSZ 401

Energy barriers of skyrmion annihilation in Pd/Fe/Ir(111) — •Stephan von Malottki[1], Bertrand Dupé[1], Pavel Bessarab[2], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany — [2]School of Engineering and Natural Sciences - Science Institute, University of Iceland, Iceland

Magnetic skyrmions are currently discussed as promising candidates for spintronic devices [1]. The understanding of skyrmion stability in realistic systems is a key issue. The calculation of minimum energy paths (MEPs) using the geodesic nudged elastic band (GNEB) method provides detailed information about energy barriers protecting skyrmions from other available states as well as reveals microscopic mechanisms of their formation and annihilation [2,3]. Up to now, such calculations have been performed with nearest-neighbour exchange [2,3]. Here, we investigate an ultrathin film of Pd/Fe/Ir(111) – a model system for skyrmion formation [4,5] – with atomistic spin dynamics, based on parameters obtained by density functional theory [5]. The energy barriers of skyrmion annihilation are calculated with the GNEB method, including the effects of frustrated exchange.

[1] A. Fert *et al.*, Nature Nanotech **8**, 152-156 (2013)
[2] P. Bessarab *et al.*, Computer. Phys. Comm. **196**, 335-347 (2015)
[3] I. Lobanov *et al.*, Phys. Rev. B **94**, 174418 (2016)
[4] N. Romming *et al.*, Phys. Rev. Lett. **114**, 177203 (2015)
[5] B. Dupé *et al.*, Nature Comm. **5**, 4030 (2014)

MA 22.7 Tue 11:30 HSZ 401

B-T phase diagram of Pd/Fe/Ir(111) — •Marie Böttcher[1,2], Bertrand Dupé[1,2], Jairo Sinova[2], and Stefan Heinze[1] — [1]University of Kiel, Germany — [2]University of Mainz, Germany

Skyrmions are localized and chiral non-collinear magnetic structures, which could be used as bits in data storage devices [1]. Such a device would require the stabilization and manipulation of skyrmions at room temperature. Recently, skyrmions have been stabilized and manipulated at 4.2 K in Pd/Fe/Ir(111) ultra-thin film [2]. Density functional theory calculations showed that skyrmions are stabilized by the competition between the Dzyaloshinskii-Moriya and the exchange interaction beyond the first nearest neighbor as well as the anisotropy [3, 4]. This competition can result in a spin glass behavior that has to be treated accordingly in Monte Carlo simulations. We performed parallel tempering Monte Carlo (PTMC) simulations [5] in order to calculate the B-T phase diagram of Pd/Fe/Ir(111). We identified order parameters that characterize the spin spiral, the skyrmion lattice and the isolated skyrmion phases. The calculated critical temperatures are in good agreement with previous calculations [4]. PTMC offers also the possibility to create and delete metastable skyrmions. Moreover, we used PTMC to calculate the chemical potentials of skyrmions and antiskyrmions at different magnetic fields, which indicates the possible creation of net topological charge. [1] A. Fert *et al.*, Nat. Nanotech. **8** (2013). [2] N. Romming *et al.*, Science **341** (2013). [3] B. Dupé *et al.*, Nat. comm. **5** (2014). [4] L. Rózsa *et al.*, Phys. Rev. B **93** (2016). [5] K. Hukushima *et al.*, Phys. Soc. Jap. **65** (1996).

MA 22.8 Tue 11:45 HSZ 401

Tailoring non-collinear magnetism by misfit dislocation lines — •Aurore Finco, Pin-Jui Hsu, André Kubetzka, Kirsten von

Bergmann, and Roland Wiesendanger — University of Hamburg, Germany

Epitaxial ultrathin films can often exhibit reconstructed surfaces because of lattice mismatch with the substrate. Unlike in pseudomorphic films, the film structure thus induces symmetry breakings and has dramatic consequences on the magnetism. In the case of a three-layer-thick Fe ultrathin film on Ir(111), the large epitaxial strain is relieved by the formation of a dense dislocation lines network. Spin-polarized scanning tunneling microscopy investigations [1] reveal that the strain is locally varying within the Fe film and that this variation affects its non-collinear magnetic state. Two types of dislocation line regions are distinguished and show spin spirals with strain-dependent periods (between 3 nm and 10 nm). Using a simple micromagnetic model, we attribute the changes of the period of the spirals to variations of the effective exchange coupling in the magnetic film. This assumption is supported by the observed dependence of the saturation magnetic field on the period of the zero field spin spiral. Moreover, magnetic skyrmions appear in an external magnetic field [2] only in one type of dislocation line areas, which we impute to their different pinning properties. Exploiting the strain relief in epitaxial ultrathin films hence appears to be an effective way to precisely and locally control magnetic states.

[1] A. Finco et al, Phys. Rev. B, in press.
[2] P.-J. Hsu et al, Nat. Nano., advance online, 2016.

MA 22.9 Tue 12:00 HSZ 401

Hosting of spin polarized surface states in spin-orbit induced bulk band gaps of W — •Hans-Joachim Elmers[1], Dmitro Kutnyakhov[1,3], Sergej V. Chernov[1], Katerina Medjanik[1], Olena Fedchenko[1], Anna Zaporozhchenko-Zymaková[1], Martin Ellguth[1], Christian Tusche[2], Jens Viefhaus[3], and Gerd Schönhense[1] — [1]Universität Mainz — [2]FZ Jülich — [3]DESY Hamburg

Spin momentum locking of surface states has attracted great interest due to potential applications in spintronics. Normal metal surfaces like W(110) and Ir(111) show surface states with energy dispersions and spin-polarization structures, which are reminiscent of topological surface states. In order to understand this phenomenon the connection of bulk and surfaces states has to be explored. Using time-of-flight momentum microscopy [1], we measured bulk bands with soft X-ray excitation within the first 3D Brillouin zone. Surface states are determined by the same method at low photon energy. The comparison of the results reveals the hosting of surface states within the gap topology of bulk bands projected on the surface Brillouin zone. [1] D. Kutnyakhov et al., Sci. Rep. 6, 29394 (2016).

MA 22.10 Tue 12:15 HSZ 401

Adsorption of pyrene molecules on Fe/W(110) — •S. Schleicher[1], J. Rawson[2], F. Matthes[1], D. E. Bürgler[1], P. Kögerler[2], and C. M. Schneider[1] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich — [2]Institute of Inorganic Chemistry, RWTH Aachen University

The chemisorption of aromatic molecules on transition metal surfaces is governed by strong hybridization of molecular π-orbitals with spin-split d-orbitals of the substrate. The resulting spin-imbalanced molecular density of states yields an induced molecular magnetic moment for strong and spin-filter properties for weak coupling [1], respectively. We study conventional pyrene molecules as a precursor for pyrene-based double-decker molecules by spin-polarized scanning tunneling microscopy/spectroscopy (SP-STM/STS) at 4 K to investigate the adsorption and hybridization properties. Molecules are deposited in UHV at room temperature, and two atomic layers of Fe on W(110) serve as ferromagnetic substrate with perpendicular magnetization. STM images reveal that the molecules remain intact upon deposition and adsorb in a flat and unique geometry. At higher coverages they self-assemble in ordered arrays. STS data reveal broad, band-like features indicating strong molecule-surface hybridization. The well-defined adsorption geometry and the strong hybridization are key requirements for the observation of spin-filtering in double-decker molecules.

[1] K.V. Raman et al., Nature 493, 509 (2013).

MA 23: Spin Dynamics and Transport: Ultrafast Effect

Time: Tuesday 9:30–12:15 Location: HSZ 403

MA 23.1 Tue 9:30 HSZ 403

Terahertz Radiation Driven Dynamics of Magnetic Domain Structures Probed by Free-Electron Laser Light — •L. Müller[1], M.H. Berntsen[2], W. Roseker[1], A. Philippi-Kobs[1], T. Golz[1], K. Bagschik[3], J. Wagner[3], R. Frömter[3], N. Stojanovic[1], C. Gutt[4], H.P. Oepen[3], and G. Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, FS-CXS, Hamburg, Germany — [2]KTH Royal Institute of Technology, Stockholm, Sweden — [3]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Hamburg, Germany — [4]Department of Physics, University of Siegen, Siegen, Germany

Controlling magnetism on ultra-fast time scales and on nanometer length scales is a challenge for modern research in magnetism, with direct implication for future data storage devices. Means for inducing dynamics on these time scales are femtosecond optical lasers and, more recently, THz sources. Probing the dynamics on a nanometer length scale has become possible with free-electron laser sources. We report on a THz-pump–XUV-probe scattering experiment on $(Co/Pt)_n$ multilayers ($n = 8,\ 16$) with perpendicular magnetic anisotropy exhibiting a maze domain pattern. An electromagnetic undulator installed at FLASH behind the permanent-magnet FEL undulator was used to produce 10-cycle linearly polarized THz pulses. The fundamental wavelength was set to $150\,\mu$m and higher harmonics down to $30\,\mu$m have been used as a pump. The resulting dynamics have been probed on femtosecond time scales by resonant magnetic small-angle scattering at the cobalt $M_{2,3}$ edge.

MA 23.2 Tue 9:45 HSZ 403

Ultrafast magnetization dynamics triggered by intense terahertz pulses — •Julius Heitz, Tom Seifert, and Tobias Kampfrath — Fritz-Haber-Institute of the Max Planck Society, Faradayweg 4-6, 14195 Berlin, Germany

We excite ferromagnetic iron thin films with sub-picosecond terahertz (THz) pulses covering the spectrum from 0.5 to 2 THz. Measurement of the magnetooptical Kerr effect (MOKE) by optical probe pulses (duration of 10 fs, center wavelength 800 nm) provides access to the time evolution of the sample magnetization. The different contributions to the magnetization dynamics are disentangled by comparing measurements with opposite THz field polarities and with different equilibrium sample magnetization. In particular, we discuss the contributions of ultrafast demagnetization and THz Zeeman torque.

The results shown here were obtained in close collaboration with the research groups of E. Beaurepaire , M. Kläui and M. Münzenberg.

MA 23.3 Tue 10:00 HSZ 403

Ultrafast excitation of coherent magnons by circularly and linearly polarized light pulses in antiferromagnetic NiO — •Christian Tzschaschel[1], Ryugo Iida[2], Tsutomu Shimura[2], Hiroaki Ueda[3], Stefan Günther[1], Takuya Satoh[2,4], and Manfred Fiebig[1] — [1]ETH Zürich, Switzerland — [2]The University of Tokyo, Japan — [3]Kyoto University, Japan — [4]Kyushu University, Japan

NiO is rapidly gaining importance in the field of antiferromagnetic magnonics. In this talk, we clarify the mechanism of ultrafast optical magnon excitation in antiferromagnetic NiO. We employed time-resolved optical two-color pump-probe measurements to study the coherent non-thermal spin dynamics. By near-infrared pumping and probing along the optical axis, we avoid the detrimental influence of birefringence. Thus, we are able to determine the mechanism behind the ultrafast optical magnon generation with linearly and circularly polarized light. For this purpose, we employ a phenomenological theory under consideration of the crystallographic and magnetic point group symmetries. Based on this new approach, we are able to describe the dynamic magneto-optical properties of NiO and derive expressions for the optically induced magnetization via the inverse Faraday effect as well as the inverse Cotton-Mouton effect. Our experimental and theoretical results are in striking agreement. This not only allows us to discriminate between the two effects, but also to extract information about the antiferromagnetic domain distribution. Moreover, we find that magnon generation via the inverse Cotton-Mouton effect is more than 30 times more efficient in NiO than via the inverse Faraday effect.

MA 23.4 Tue 10:15 HSZ 403

Ultrafast structural and magnetization dynamics of the Skyrmion crystal GaV_4S_8 — •Evgeniia Slivina[1], Prashant Padmanabhan[1], Rolf B. Versteeg[1], Sándor Bordács[2], István Kézsmárki[2], and Paul H. M. van Loosdrecht[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany — [2]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, Hungary

GaV_4S_8 is a lacunar spinel, notable for its unusual para-to-ferroelectric phase transition and the emergence of novel magnetic ground states below the Néel temperature. One of the latter - the Néel Skyrmion - was recently observed, but to date, little is known about the coherent control of magnetic excitations in this material. Here, we employ time-resolved magneto-optical Kerr effect spectroscopy to demonstrate the coherent excitation of Néel-type Skyrmions and other magnetic ground states in GaV_4S_8. In addition, we measure the time-resolved differential reflectivity and coherent phonon dynamics to elucidate the Jahn-teller induced para-to-ferroelectric phase transition in this material.

MA 23.5 Tue 10:30 HSZ 403

Picosecond time-evolution of Cu_2OSeO_3's helimagnetic order parameter after photoexcitation studied by time-resolved spontaneous Raman spectroscopy — •Rolf B. Versteeg[1], Jingyi Zhu[1], Christoph Boguschewski[1], Petra Becker[2], and Paul H.M. van Loosdrecht[1] — [1]II. Physikalisches Institut, Universität zu Köln, Cologne, Germany — [2]Abteilung Kristallographie, Institut für Geologie und Mineralogie, Cologne, Germany

Time-resolved Raman spectroscopy is a seldom used tool in the investigation of picosecond magnetization dynamics. This is mostly due to a combination of the low inelastic light scattering rate, and the restrictions on time-resolution, and needed spectral resolution. A successful realization of such an experiment would however lead to valuable insights into symmetry changes after optical perturbation, quasiparticle population statistics, and excitation energy changes on ultrafast timescales.

Here, we present the ultrafast dynamics of helimagnetic order in the chiral magnet Cu_2OSeO_3 studied by time-resolved picosecond spontaneous Raman spectroscopy. This material has attracted significant research interest due to the presence of a Skyrmion lattice phase. The ground state of this material consists of helimagnetically ordered $S = 1$ spin clusters, which are composed of 3-up-1-down Cu $S = 1/2$ spins. The magnetic excitations within the spin-cluster are Raman-active, and serve as a probe for helimagnetic order. We show that after photoexcitation the helimagnetic order "melts" through spin-lattice relaxation on typical timescales of ~ 100 ps.

15 min. break

MA 23.6 Tue 11:00 HSZ 403

Off-resonant excitation of Co films by intense single-cycle THz pulses: computer simulations and experiments — •Andreas Donges[1], Mostafa Shalaby[2], Carlo Vicario[2], Karel Carva[3], Peter M. Oppeneer[4], Christoph P. Hauri[2], and Ulrich Nowak[1] — [1]Universität Konstanz, DE-78457 Konstanz, Germany — [2]SwissFEL, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland — [3]Charles University, CZ-12116 Praha 2, Czech Republic — [4]Uppsala University, SE-75120 Uppsala, Sweden

It was recently demonstrated that THz radiation is an efficient tool to coherently excite ferro- [1] and antiferromagnets [2] on the sub-ps time scale. With the availability of more intense THz sources, there is experimental evidence that the excitation of the magnetization becomes incoherent–an effect that is not understood yet. We performed multiscale modeling simulations, starting from ab-initio calculations of the Heisenberg exchange constants for the spin Hamiltonian of Co. We further used the stochastic Landau-Lifshitz-Gilbert equation in combination with an extended two-temperature model, to compute the spin dynamics response to a THz bullet. The results are compared to our THz pump–NIR MOKE probe measurements, for fluences up to $90\,mJ/cm^2$. From our findings we conclude that the coherent oscillations are caused by a direct coupling of the spins to the Zeeman field of the THz pulse, whereas the incoherent dynamics is due to the electric field which affects the spins indirectly, via heating of the electrons.

[1] C. Vicario, et al., *Nature Photonics*, **7**, 720-723 (2013).
[2] T. Kampfrath, et al., *Nature Photonics*, **5**, 31-34 (2011).

MA 23.7 Tue 11:15 HSZ 403

Relativistic theory of magnetic inertia in ultrafast spin dynamics — •Ritwik Mondal, Marco Berritta, Ashis K. Nandy, and Peter M. Oppeneer — Department of Physics and Astronomy, Uppsala University, Sweden

The influence of possible magnetic inertia effects has recently drawn attention in ultrafast magnetization dynamics and switching[1]. Here we derive rigorously a theory of inertia in the Landau-Lifshitz-Gilbert equation on the basis of the Dirac-Kohn-Sham framework. Using the Foldy-Wouthuysen transformation up to the order of $1/c^4$ gives the 2nd order time-derivative of magnetization in the dynamical equation of motion. Thus, the inertia damping is a higher order spin-orbit coupling effect, as compared to the Gilbert damping[2]. It is therefore expected to play a role only on ultrashort timescales (sub-picoseconds)[3]. We also show that the Gilbert damping and *intrinsic* inertia damping are related to one another[4] through the imaginary and real parts of the magnetic susceptibility tensor respectively.

[1]A. V. Kimel *et al.*, Nature Phys. **5**, 727 (2009). [2]R. Mondal, M. Berritta and P. M. Oppeneer Phys. Rev. B **94**, 144419 (2016). [3]M.-C. Ciornei, J. M. Rubí and J.-E. Wegrowe, Phys. Rev. B **83**, 020410(R) (2011). [4]M. Fähnle, D. Steiauf and C. Illg, Phys. Rev. B **84**, 172403 (2011).

MA 23.8 Tue 11:30 HSZ 403

Ultrafast Spin Transfer Torque Generated by a Femtosecond Laser Pulse — •Pavel Baláž[1], Martin Žonda[1], Karel Carva[1], Pablo Maldonado[2], and Peter Oppeneer[2] — [1]Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, CZ-12116 Prague 2, Czech Republic — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-75120 Uppsala, Sweden

A phenomenon of laser pulse-induced ultrafast demagnetization of magnetic material on femtosecond time-scale, is connected with number of open questions. Particularly, in transition metals and their alloys featuring spin polarized 3d valence band and conduction 4s band, a laser pulse can excite electrons from the d band into the s one with higher electron mobility. Consequently, the nonequilibrium hot charge carriers migrate away from the laser spot and reduce the local magnetic moment. This process is described by the superdiffusive spin transport model [1], which takes into account scattering of hot electrons on atomic sites leading to nonequilibrium avalanches of excited electrons.

In this work, we study the spin transfer torque and magnetization dynamics induced by a spin current of hot electrons in spin valve consisted of two magnetic layer with perpendicular magnetizations separated by a nonmagnetic one. To this end, we developed a four-channel model of spin transport, which allows us to calculate spin transfer torque and describe magnetization dynamics.

[1] M. Battiato, K. Carva, P. Oppeneer Phys. Rev. Lett. 105, 027203 (2010); Phys. Rev. B 86, 024404 (2012).

MA 23.9 Tue 11:45 HSZ 403

TDDFT simulation of ultrafast demagnetization: Spin Current vs Spin Flips — •Peter Elliott, Kevin Krieger, J. Kay. Dewhurst, Sangeeta Sharma, and E.K.U. Gross — Max-Planck Institute of Microstructure Physics

We apply the ab-initio simulation method of time dependent density functional theory (TDDFT) to shed light on the underlying physics of ultrafast demagnetization in ferromagnetic materials due to intense laser pulses. A key finding of our work is that the spin-orbit interaction (SOI) can be responsible for this ultrafast loss of moment, under the right circumstances. In this work we compare the loss of moment due to 1) spin transport (i.e. transport of the moment from a ferromagnetic layer into a substrate) and 2) SOI demagnetization happening in the magnetic layer itself. For the interfaces we study, we find that both processes contribute equally to the demagnetization of the ferromagnet. Furthermore we predict that if the substrate has strong SOI character (e.g. Pt), there can even be SOI type demagnetization of the moment that was transported into the substrate.

MA 23.10 Tue 12:00 HSZ 403

Monte Carlo simulation of the non-equilibrium spin dynamics — •Johan Briones and Baerbel Rethfeld — Department of Physics and Optimas Research Center, University of Kaiserslautern,

Germany

A Monte Carlo simulation model will be developed in order to study the ultrafast demagnetization process due to the interaction of an ultrashort laser pulse with a ferromagnetic material. In this stochastic model, the electron-electron interaction will be considered, as well as spin-dependent inelastic and elastic scattering processes. Furthermore, the magnetization dynamics will be investigated by using a two-bands dynamic model. The model will be first applied to the case of Nickel. The results of this simulation will provide information regarding the time evolution of the electron number, energy distribution, energy dissipation and the quenching of the magnetization.

The long-term perspective of this project is to develop a model that can describe the non-equilibrium transport and its effect on magnetization dynamics.

MA 24: Focus: Microwave and THz Properties, Developments and Applications of Dielectric Materials

This dedicated focus session represents applications of dielectric materials from electronics up to Mega-Watt Fusion Heating systems. Part of the session are the different applications of dielectrics and the production and properties of these materials as well. Goal of the session is to join different fields to generate new ideas for dielectric applications and developments.

Organizer: Theo Scherer KIT Karlsruhe

Time: Tuesday 9:30–12:20 Location: GER 37

Topical Talk MA 24.1 Tue 9:30 GER 37

Synthesis of large-area single-crystal diamond by heteroepitaxy for application as dielectric window material — •Matthias Schreck, Stefan Gsell, and Martin Fischer — Institut für Physik, Universität Augsburg, 86135 Augsburg, GERMANY

Due to ist low dielectric loss tangent in combination with excellent mechanical properties and the unrivalled thermal conductivity, diamond is the optimum window material for the transmission of high power millimeter waves. Polycrystalline discs with diameters of about 100 mm synthesized by microwave plasma chemical vapor deposition (MWPCVD) are already in use as gyrotron exit windows or as injection windows for future thermonuclear fusion reactors. Since imperfections like graphitic bonds and C-H groups at grain boundaries still give rise to power absorption, the use of single crystals promises even lower loss tangents thus facilitating higher power levels. The present contribution reviews the efforts towards the synthesis of wafer-scale single-crystal diamond by heteroepitaxial growth using MWPCVD. The search for the optimum substrate material, the development of appropriate nucleation methods and the concepts for the scaling to wafer size are described. Particular attention is paid to dislocations which represent the crucial defect type. The role of dislocations in the development of intrinsic stress, the reduction of their density by growth of thick layers and by advanced deposition concepts is broadly discussed. Finally, the present state-of-the-art in terms of crystal quality and sample size is described.

MA 24.2 Tue 10:00 GER 37

Electron Cyclotron systems in future Fusion Power Plants, using dielectric microwave transmission windows — •Giovanni Grossetti, Gaetano Aiello, Francesco Mazzocchi, Andreas Meier, Theo Scherer, Sabine Schreck, Peter Spaeh, Dirk Strauss, and Alessandro Vaccaro — KIT, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein Leopoldshafen

Nuclear fusion has the potential to be a nearly unlimited, safe and CO2-free friendly energy source which would allow coping with the increasing demand in energy consumption, currently heavily based on the fast depleting fossil fuels (over 80%). Fusion devices are ring-shaped metal vessels provided with numerous openings for diagnostic systems and additional heating systems. One of the most important one is the Electron Cyclotron Heating and Current Drive system (ECH&CD), that aims to provide high power (several MW) in the rage of hundreds of GHz into the plasma, a hot gas composed by Deuterium and Tritium nuclei. In this paper we present the possible configurations of ECH&CD systems required by future fusion power plants. The focus will be on launching antenna systems without movable parts close to the plasma (i.e. remote steering concepts and truncated waveguides) and chemical vapor deposition (CVD) diamond windows. The latter are crucial to ensure flexibility in operation of Radio Frequency source (Gyrotrons), when the latter are capable to tune the beam frequency to the desired resonance.

Topical Talk MA 24.3 Tue 10:20 GER 37

Design, materials composition and manufacturing of components for advanced modular gyrotron prototypes — •Sebastian Ruess[1], Gaetano Aiello[2], Gerd Gantenbein[1], Tomasz Rzesnicki[1], Theo Scherer[2], Dirk Strauss[2], Manfred Thumm[1], Jörg Weggen[1], and John Jelonnek[1] — [1]IHM, — [2]IAM-WAP, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

In frame of EUROfusion, Karlsruhe Institute of Technology (KIT) is performing major research on future gyrotrons for microwave heating of fusion plasma. Major factor for the success is to gain a fundamental understanding about the basic physics, the right materials composition in the assembly and, finally, the manufacturing technologies for future 2-MW gyrotrons operating in the frequency range from 170 GHz up to 240 GHz. The components of a first pre-prototype 2-MW, 170 GHz long-pulse gyrotron were already successfully in-house manufactured with an excellent quality. Furthermore, welding and solder joints have been achieved with an excellent leakage rate below < 10-12 mbar l/s. In particular, excellent solder joints between CVD diamond and copper as well as stainless steel and dispersion strengthened copper (Glidcop) were achieved. In addition, KIT is strongly involved in the development of ultra-low loss diamond discs for high power gyrotrons and fusion power plants. The ongoing KIT developments are focusing on the manufacturing, joining technologies and cooling concepts for advanced broadband CVD diamond double-disk and Brewster-angle windows.

20 min. break

Topical Talk MA 24.4 Tue 11:10 GER 37

Dielectric diamond window for the ITER EC H&CD Upper Launcher: design, analysis and qualification — •Gaetano Aiello[1], Mario Gagliardi[2], Giovanni Grossetti[1], Francesco Mazzocchi[1], Andreas Meier[1], Gabriella Saibene[2], Sabine Schreck[1], Peter Spaeh[1], Dirk Strauss[1], Alessandro Vaccaro[1], and Theo Scherer[1] — [1]Karlsruhe Institute of Technology, Institute for Applied Materials, D-76021 Karlsruhe, Germany — [2]Fusion for Energy, E-08019 Barcelona, Spain

The diamond window is a sub-component of the EC H&CD Upper Launcher and it is part of the ITER first vacuum and tritium confinement system while allowing the transmission of high power microwave beams from the gyrotrons into the plasma. The window consists of an ultra-low loss CVD diamond disc brazed to two copper cuffs and this structure is then integrated into a metallic housing by welding. Being a Protection Important Component, the most stringent requirements in the ITER safety, quality, seismic, vacuum and tritium classifications apply. In this work, we present the development of the window design and the qualification process aiming to meet the requirements via the applicable ASME code and a dedicated program. The window is in fact a unique component that cannot be entirely covered by Codes and Standards. At KIT, FABRY-PEROT resonators measure the loss tangent of the diamond disc which is then used as input to the FEM analyses aiming to validate the design. In the context of the OPE467 contract with F4E, technical specifications are approaching the final phase for the manufacturing and testing of two window prototypes.

MA 24.5 Tue 11:40 GER 37

THz Diagnostics for fusion - A new challenge for dielectric windows — •Francesco Mazzocchi, Giovanni Grossetti, Dirk Strauss, and Theo Scherer — Karlsruhe Instiüt für Technologie, Hermann Von Helmholtz Platz 1, 76344, Eggenstein Leopoldshafen

Polarimetry is a reliable methodology to estimate fundamental plasma parameters such as electronic density and poloidal field from the measure of the Faraday rotation angle. In this work we present a conceptual study of an innovative polarimetric system. The device foresees multiple lines of sight, so that the estimation of the aforementioned parameters can be performed at different cords. Dielectric windows play a fundamental role in this case, given the number beamlines that require access to the vacuum vessel. In order to have an appreciable Faraday rotation, sources in the range of the low THz are needed. Quantum Cascade Lasers represent a very promising solution but to work at low frequency (around 1.6 THz) they require cryogenic temperatures. The power output of such devices is still several order of magnitudes below the level guaranteed by the more common laser sources employed so far, such as DCN gas lasers. Therefore a strong focus on the production and characterization of ultra low loss dielectric materials (e.g. diamond, sapphire) for the cryostat and torus windows in the THz range is mandatory, to ensure the polarimeter probe beam absorption to be negligible and the device to work correctly.

MA 24.6 Tue 12:00 GER 37

Dielectric investigation methods in the THz frequency range — •Theo Scherer, Francesco Mazzocchi, and Giovanni Grossetti — Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany

CVD diamond disks for high power heating applications are being investigated by different low- and high power measurement setups in the frequency range of > 100 GHz. To understand the loss mechanisms in diamond material the determination of the frequency dependence of dielectric constant and loss tangent at higher frequencies up to several THz is essential. It is well known from the experience with other window materials for high power fusion applications (ECRH) like silicon or sapphire, electrons and phonons are responsible for microwave losses. In diamond the sp2-carbon content and surface roughness determines surface losses. Additionally, the electronic surface states of such dielectrics for different chemical finishing of the diamond disks can be studied in the THz region. Different resonator setups to determine dielectric properties in the THz-range will be discussed.

MA 25: Ferroics - Domains, Domain Walls and Skyrmions I

Subsequently to the symposium "Novel functionality and topology-driven phenomena in ferroics and correlated electron systems" four Focus Sessions "Ferroics - Domains, Domain Walls and Skyrmions I - IV" cover recent developments in analyzing (multi-)ferroic materials, investigations of domain and domain-wall phenomena, the introduction of novel key concepts as well as methods for advanced characterization.

Chairs: Markus Garst and Manuel Bibes

Time: Tuesday 9:30–13:30 Location: WIL B321

Topical Talk MA 25.1 Tue 9:30 WIL B321

Room temperature skyrmions and robust metastable skyrmion states in $Co_8Zn_8Mn_4$ — •Jonathan White[1], Kosuke Karube[2], Nicole Reynolds[1,3], Jorge Gavilano[1], Hiroshi Oike[2], Akiko Kikkawa[2], Fumitaka Kagawa[2], Yusuke Tokunaga[4], Henrik Ronnow[3], Yoshinori Tokura[2,5], and Yasujiro Taguchi[2] — [1]Paul Scherrer Institut, Switzerland — [2]RIKEN CEMS, Wako, Japan — [3]EPFL, Switzerland — [4]Department of Advanced Materials Science, University of Tokyo, Japan — [5]Department of Applied Physics, University of Tokyo, Japan

Magnetic skyrmions are being intensely studied in various noncentrosymmetric magnets. Among them, the chiral cubic magnets are well-known to host a hexagonal skyrmion lattice as a thermodynamic equilibrium state. However, this state exists only over a narrow temperature and magnetic field region just below the magnetic transition temperature. Using both ac susceptibility and neutron scattering, we study metastable Skyrmion states in the room-temperature skyrmion host material $Co_8Zn_8Mn_4$. These states, created by a conventional field-cooling through the equilibrium skyrmion state, survive over the major part of the phase diagram, including down to zero temperature and up to the critical magnetic-field of the ferromagnetic transition. Furthermore, the metastable skyrmion lattice is observed to transform between conventional hexagonal and a novel square-like coordinations upon varying the temperature and magnetic field. These findings exemplify the topological robustness of the once-created skyrmions, and establish metastable states as a promising technological platform.

MA 25.2 Tue 10:00 WIL B321

Universal relations between electromagnetic response functions: towards a first-principles description of magnetoelectric materials — •Giulio Schober[1] and Ronald Starke[2] — [1]Institute for Theoretical Physics, Heidelberg University, Philosophenweg 19, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, TU Bergakademie Freiberg, Leipziger Str. 23, 09596 Freiberg

Based on modern microscopic approaches to electrodynamics of materials, we systematically investigate the mutual functional dependencies of induced, external and total electromagnetic field quantities. This allows for a unified, relativistic description of the electromagnetic response without assuming the material to be composed of electric or magnetic dipoles. Using this approach, we derive universal (material-independent) relations between electromagnetic response functions such as the dielectric tensor, the magnetic susceptibility and the microscopic conductivity tensor. Our formulae can be reduced to well-known identities in special cases, but more generally include the effects of inhomogeneity, anisotropy, magneto-electric cross-coupling and relativistic retardation. If combined with the Kubo formalism, they would therefore lend themselves to the ab initio calculation of all linear electromagnetic response functions, thus paving the way for a first-principles description of magneto-electric materials for spintronics applications.

MA 25.3 Tue 10:15 WIL B321

Giant Rashba effect in ferroelectrics from first principles — •Louis Ponet[1,2], Urko Petralanda[1], Silvia Picozzi[3], and Sergey Artyukhin[1] — [1]Quantum Materials Theory, Istituto Italiano di Tecnologia, Via Morego, 30, Genova, Italy. — [2]Scuola Normale Superiore, Piazza dei Cavalieri, 7, Pisa — [3]CNR-SPIN, UOS L'Aquila, Via Vetoio, 10, Coppito, L'Aquila (IT)

Spintronics has been an exciting area in the last decades, due to a promise for devices that exploit the existence of spin-polarized states [1]. Important applications include storage media, where the use of spins to store data has been widespread since the earliest days of computing. However, these storage devices use magnetic fields to orient magnetic domains, an approach that is making further miniaturization increasingly difficult. A possible solution could be using spin torques provided by spin-polarized currents for more fine-grained and efficient control of magnetic domains. However, to access these states in electronics, there is also a pressing need for electric control of the states, which was recently demonstrated in materials that showcase an anomalously large Rashba-effect [2]. This effect allows for electric control of very highly spin-polarized states, but the origin of the behaviour is not thoroughly understood yet. We used model Hamiltonians and ab-initio calculations to examine the effect.

[1] S. D. Bader and S. S. P. Parkin, Spintronics, Ann. Rev. Cond. Matt. Phys. 1, 71 (2010).

[2] D. Di Sante, P. Barone, R. Bertacco, S. Picozzi, Advanced Materials, 25, 509 (2013).

15 min. break

MA 25.4 Tue 10:45 WIL B321

Constant-current calligraphic domain-inversion in lithium-niobate crystals — •Christoph S. Werner[1], Simon J. Herr[1], Karsten Buse[1,2], and Ingo Breunig[1] — [1]Department of Microsystems Engineering, University of Freiburg — [2]Fraunhofer Institute for Physical Measurement Techniques, Freiburg, Germany

Lithium-niobate is commonly applied as a nonlinear crystal in nonlinear, optical frequency converters. In order to phase-match the interacting waves, a periodic domain inversion of the crystal is often necessary. The standard method to create the necessary domain pattern uses a structured electrode which defines the position of the domains. While this method is good in batch-processing large quantities of crystals, it is unflexible for prototyping domain patterns since every pattern requires an individual photolithographic mask. We present a technique to rapidly create high-quality domain-structures in congruent-melting, MgO-doped lithium-niobate crystals by defining the position of the domain with a metallic needle. Therefore, the needle is moved along the desired position of the domain. A current-control-loop maintains a constant current and adjusts the necessary poling-voltage accordingly while the needle moves across the crystal. This ensures a high-quality domain-formation independent of the crystal orientation. This method is especially useful for creation of radially-poled domains which are suited for whispering-gallery resonators.

MA 25.5 Tue 11:00 WIL B321

Giant charged-domain-wall conductivity in lithium-nioabte — •Simon J. Herr[1], Christioph S. Werner[1], Cina Razzaghi[2], Elisabeth Soergel[2], Boris Sturman[3], Karsten Buse[4], and Ingo Breunig[1] — [1]Department of Microsystems Engineering, University of Freiburg — [2]University of Bonn, Bonn, Germany — [3]Institute for Automation and Electrometry of Russian Academy of Science, Novosibirsk, Russia — [4]Fraunhofer Institute for Physical Measurement Techniques, Freiburg, Germany

Charged-domain-walls in ferroelectric materials are known to show increased conductivity compared to the bulk-material. These domain-walls could play the key-role in a new type of electronic or electro-optic devices making use of the functional features of the host crystals. So far, the limiting factors are the high resistivity of the domain walls and the lack of a mechanism to create an ohmic interface to the domain-wall. Based on our method of calligraphic domain-inversion, we were able to create conducting domain-walls in lithium-niobate which show a highly increased conductivity, comparable to that of semiconductor materials. Further, we demonstrate that we can achieve diode-like behaviour as well as ohmic conduction.

MA 25.6 Tue 11:15 WIL B321

Functional electronic inversion layers at ferroelectric domain walls — •Jakob Schaab[1], Julia A. Mundy[2], Yu Kumagai[1], Andres Cano[3], Massimiliano Stengel[4], Darrel G. Schlom[2], David A. Muller[2], Ramamoorthy Ramesh[5], Manfred Fiebig[1], Nicola A. Spaldin[1], and Dennis Meier[6] — [1]ETH Zürich — [2]Cornell University — [3]CNRS, Université de Bordeaux — [4]ICMAB-CSIC Barcelona — [5]UC Berkeley — [6]NTNU Trondheim

Ferroelectric domain walls hold great promise as functional 2D-materials because of their unusual electronic properties. Particularly intriguing are the so-called charged walls where a polarity mismatch causes local, diverging electrostatic potentials requiring charge compensation and hence a change in the electronic structure. These walls can exhibit significantly enhanced conductivity and serve as a circuit path. The development of all-domain-wall devices, however, also requires walls with controllable output to emulate electronic nano-components such as diodes and transistors.

Here, we will present electric-field control of the electronic transport at ferroelectric domain walls. We reversibly switch from resistive to conductive behavior at charged walls in semiconducting $ErMnO_3$. We relate the transition to the formation - and eventual activation - of an inversion layer that acts as the channel for the charge transport. Our conductive atomic force microscopy (cAFM) and electron energy loss spectroscopy (EELS) data provide new insight to the domain-wall physics in ferroelectrics and foreshadow the possibility to design elementary digital components for all-domain-wall circuitry.

MA 25.7 Tue 11:30 WIL B321

In-situ 3D observation of the domain wall dynamics of triglycine sulfate upon ferroelectric phase transition — •Lukas Wehmeier, Thomas Kämpfe, Alexander Haussmann, and Lukas M. Eng — Institute of Applied Physics, Technische Universität Dresden, Dresden, Germany

Second harmonic generation microscopy (SHGM), also known as Cherenkov-SHG, allows for the 3-dimensional (3D) observation of ferroelectric domain walls (DWs) across millimeter-thick bulk materials [1,2]. We apply here SHGM in order to quantify the DW dynamics in triglycine sulfate (TGS) single crystals upon the ferroelectric-to-paraelectric phase transition around Tc = 49°C. Although having been in the focus of many works, this second-order phase transition is still of fundamental interest, especially in the view of our novel 3D techniques at hand or with respect to explore charged domain walls [3-5] in bulk single crystals. SHGM allows, for the first time, to watch the time-resolved dynamics in real time and in 3D, here when crossing the Curie temperature Tc. Furthermore, we also monitor the spike domain growth in TGS using SHGM. Spike domains are an excellent example of transient charged domain walls that topologically differ completely from the equilibrium bulk domain structure.

[1] T. Kämpfe et al., Phys. Rev. B 89, 035314 (2014)
[2] T. Kämpfe et al., Appl. Phys. Lett. 107, 152905 (2015)
[3] M. Schröder et al., Mater. Res. Express 1, 035012 (2014)
[4] M. Schröder et al., Adv. Funct. Mater. 22, 3963 (2012)
[5] T. Sluka et al., Nat. Commun. 3, 748 (2012)

MA 25.8 Tue 11:45 WIL B321

Anisotropic domain wall conductivity (DWC) of neighboring 180° DWs in $LiNbO_3$ single crystals — •Shuyu Xiao[1,2], Thomas Kaempfe[2], Yaming Jin[1], Alexander Haussman[2], Xiaomei Lu[1], and Lukas Eng[2] — [1]Physics School, Nanjing University, 210093 Nanjing, P. R. China — [2]Institute of Applied Physics, Technical University of Dresden, George-Baehr-Strasse 1, Dresden, Germany

Investigating the origin and nature of the domain wall conductivity (DWC) in different ferroelectric materials such as $BiFeO_3$ [1], $ErMnO_3$ [2] and $LiNbO_3$ (LNO) [3] is of a major scientific interest today. Here, we report on anisotropic DWC, as found between neighboring head-to-head (h2h) and tail-to-tail (t2t) 180° DWs in z-cut LNO single crystals. We applied conductive atomic force microscopy (cAFM) to quantify the local DW currents, probed the local polarization by piezo-response force microscopy (PFM), and mapped the 3D domain topology via Cherenkov Second Harmonic Generation (CSHG) microscopy [4]. The origin of the different DWC between h2h and t2t is studied by both phenomenological theories and dipole modelling assuming a quantum-mechanical tunneling process for electron transport. The domain wall inclination is found to account for the different conductivities in neighboring 180° DWs, while the material symmetry determines whether h2h or t2t DW becomes more conductive. In addition, domain wall roughness plays an important role in DWC as well.

[1] J. Seidel et al., Nat. Mater., 8 (2009), 229 [2] D. Meier et al., Nat, Mater., 11 (2012), 284 [3] M. Schroeder et al., Mater. Res. Express., 1 (2014), 035012 [4] T. Kaempfe et al., Phys. Rev. B, 89 (2014), 035314

15 min. break

MA 25.9 Tue 12:15 WIL B321

Electric conduction and dynamics of ferroelectric domain walls in $SrTiO_3$ — •Haijiao Harsan Ma, Daniel Kohlberger, Matthias Lange, Sebastian Scharinger, Reinhold Kleiner, and Dieter Koelle — Physikalisches Institut and Center for Quantum Science (CQ) in LISA$^+$, Universität Tübingen, Germany

Domain walls in $SrTiO_3$ could play a significant role in future oxide electronics, given their small size at the nanoscale as well as the fact that their occurrence can be controlled by an external electric field. Here, we report on the low-temperature electric conductance properties of domain walls in $SrTiO_3$ and their response to an external electric field. These properties are probed by using a combination of low-temperature scanning electron microscopy, polarized light microscopy and electric transport measurements. Our measurements show that above the threshold electric field $\sim 1\,$kV/cm for field-induced electric order [1], the domain walls show strongly increased conductance as compared to the bulk $SrTiO_3$. We will also address observations of complex dynamic behavior of the domain wall conductance properties.

[1] H. J. Harsan Ma *et al.*, Phys. Rev. Lett. **116**, 257601 (2016).

MA 25.10 Tue 12:30 WIL B321

Conductive domain walls in $SrMnO_3$ thin films under epitaxial tensile strain — •Lokamani Lokamani[1], Carina Faber[3], Peter Zahn[1], Nicola Spaldin[3], and Sibylle Gemming[1,2] — [1]Institute of Ion Beam Physics and Materials Research, HZDR, 01314 Dresden, Germany — [2]Institute of Physics, Technische Universität, 09107 Chemnitz, Germany — [3]Materials Theory, ETH, 8093 Zürich, Switzerland

Strontium manganate ($SrMnO_3$), a perovskite polymorph, exhibits cubic structure at low temperatures, which transforms into a hexagonal one at high temperatures. Density-functional calculations showed earlier, that under tensile strain the ground state of bulk $SrMnO_3$ corresponds to a G-type-antiferromagnetic (G-AFM) cubic structure. If deposited as epitaxially strained thin film a rearrangement of the MnO_6 coordination polyhedra was calculated, which is antiferrodistortive in the plane parallel to the substrate[1]. Recently, ferroelectric domains have been observed experimentally in 20nm thin films of $SrMnO_3$ under 1.7% tensile strain on (001)-oriented LSAT[2]. Strikingly, the domain walls were found to be electrically insulating, rendering the domains to form stable nano-capacitors.

Here, we present a first-principle investigation of the domain wall formation in epitaxially strained $SrMnO_3$ and a discussion of the electronic properties.

[1] J. H. Lee et al., PRL 104, 207204 (2010)
[2] C. Becher et al., Nature Nanotechnology 10, 661 (2015)

Funding by VI Memriox(VH-VI-422) & Nanonet(VH-KO-606)

MA 25.11 Tue 12:45 WIL B321

Local probe studies of switching and current dynamics in Pb(Zr$_{0.2}$Ti$_{0.8}$)O$_3$ thin films — •Philippe Tückmantel[1], Iaroslav Gaponenko[1], Stefano Gariglio[1], Benedikt Ziegler[1], Joshua Agar[2], Lane W. Martin[2], and Patrycja Paruch[1] — [1]DQMP, University of Geneva, Geneva, Switzerland — [2]DMSE, University of California, Berkeley, USA

Defects and electrostatic boundary conditions have been shown to greatly impact the intrinsic configuration, geometry and growth dynamics of polarization domains in ferroelectric thin films. Indeed, defects can induce different switching dynamics, where the polarization reversal can be dominated by the nucleation of new domains or by the lateral growth of existing domains. Defects such as oxygen vacancies can also play an important role in controlling the electrical conduction at ferroelectric domain walls and, in conjunction with electrostatic boundary conditions can even allow fully reversible control of this phenomenon.

Here, we present our results on $Pb(Zr_{0.2}Ti_{0.8})O_3$ thin films showing both different switching dynamics and different domain wall current behaviours in samples grown by pulsed laser deposition and off-axis RF magnetron sputtering. Using piezoresponse force microscopy (PFM) and conductive atomic force microscopy (c-AFM) in ultra-high vacuum, we study the nanoscale nucleation and motion of domains as a function of applied tip voltage and their relation to the corresponding currents and defect densities.

MA 25.12 Tue 13:00 WIL B321

Enhancement of local photovoltaic current at ferroelectric domain walls in BiFeO$_3$ — •Ming-Min Yang and Marin Alexe — Department of Physics, University of Warwick, Coventry, UK

Domain walls, which are intrinsically two-dimensional nano-objects exhibiting nontrivial electronic and magnetic behaviors, have been proven to play a crucial role in photovoltaic properties of ferroelectrics. Despite this recognition, the electronic properties of domain walls under illumination until now have been accessible only to macroscopic studies and their effects upon the conduction of photovoltaic current still remain elusive. The lack of understanding hinders the developing of nanoscale devices based on ferroelectric domain walls. Here, we directly characterize the local photovoltaic and photoconductive properties of 71 degree domain walls on $BiFeO_3$ thin films with a nanoscale resolution. Local photovoltaic current, proven to be driven by the bulk photovoltaic effect, has been probed over the whole illuminated surface by using a specially designed photoelectric atomic force microscopy and found to be significantly enhanced at domain walls. Additionally, spatially resolved photoconductive current distribution reveals a higher density of excited carriers at domain walls in comparison with domains. Our measurements demonstrate that domain wall enhanced photovoltaic current originates from its high conduction rather than the internal electric field. This photoconduction facilitated local photovoltaic current is likely to be a universal property of topological defects in ferroelectric semiconductors.

MA 25.13 Tue 13:15 WIL B321

Reconfigurable domain wall conductance by inclination tuning — •Thomas Kämpfe[1], Bo Wang[2], Scott Johnston[3], Eric Y. Ma[3], Alexander Haussmann[1], Hui Hu[4], Zhi-Xun Shen[3], Long-Qing Chen[2], and Lukas M. Eng[1] — [1]Institute of Applied Physics and Center for Advancing Electronics (CFAED), TU Dresden, Germany — [2]Department of Materials Science and Engineering, Pennsylvania State University, University Park, USA — [3]Department of Applied Physics and Geballe Laboratory for Advanced Materials (GLAM), Stanford University, USA — [4]School of Physics, Shandong University, Jinan, China

We report on ferroelectric domain wall (DW) conductance in lithium niobate thin films that allows reproducibly writing/erasing DWs by proper voltage adjustment. The DWs are conductive and show persistent DWC at least for two months. Mandatory to DW conductance is a minimal DW inclination that promotes electron transport without illumination [1]. We proof this dependence indirectly: we compare cAFM measurements for domains written at various writing voltages and compare it with the simulated inclination angles obtained from phase-field modeling, which shows a decrease in inclination the larger the writing voltage. The conductance was further investigated by scanning-microwave impedance microscopy (sMIM) revealing a conductivity of about 100 to 1000 S/m at 1 GHz, hence an increase of about 10^{11} to the bulk conductivity of about 10^{-8} S/m.

[1] M.Schröder et.al., Adv. Funct. Mater. 22, (18), 3936 (2012)

MA 26: Thin Films: Magnetic Coupling Phenomena / Exchange Bias

Time: Tuesday 14:00–16:00 Location: HSZ 101

MA 26.1 Tue 14:00 HSZ 101

Analysis of magnetic anisotropies in polycrystalline exchange bias multilayer systems in dependence on field cooling temperature and thickness of buffer layer — •Laura Weidenfeller, Nicolas David Müglich, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Straße 40, D-34125 Kassel

The influence of the thickness of the buffer layer and the induced anisotropy by the external magnetic field due to different cooling temperatures on the exchange bias is shown. Different thicknesses of the buffer layer combined with field coolings at specific temperatures are measured with angular resolved MOKE.

Using a modified Stoner-Wolfarth model, the measurement results allow conclusions about the grain size distribution in the antiferromagnet which indicates the necessity of a superposition of lognormal functions for the distribution. Further, all used systems show nearly the same exchange bias field, however, induced at different field cooling temperatures. Inspite of no changes in the exchange bias field at a specific temperature, the coercivity instead shows differences.

MA 26.2 Tue 14:15 HSZ 101

Improved thermal stability of doped MnN/CoFe exchange bias systems — •Mareike Dunz and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

In spinelectronics, the exchange bias effect is used to pin a ferromagnetic electrode to an antiferromagnetic film. This is crucial in GMR or TMR devices to allow for clearly separated switching states. Recently, we reported that polycrystalline MnN/CoFe bilayers show exchange bias fields of up to 1800 Oe at room temperature [1]. However, to make up for other commonly used antiferromagnets, some features of MnN like thermal stability and critical layer thickness require improvement. Here, we report on the effects of doping MnN with Fe, Si, or Y in order to optimize these properties.

Exchange bias systems with different doping concentrations and MnN layer thicknesses were prepared via reactive co-sputtering. Post-annealing series were performed to detect changes in the thermal stability. We show that doping with elements enhancing the nitrogen bonds in the MnN lattice, like Si or Y, indeed yields exchange bias systems that are stable up to higher temperatures. Y doped MnN layers with doping concentrations below 2% result in systems that show exchange bias fields higher than 1000 Oe for annealing temperatures up to 500°C.

[1] M. Meinert, B. Büker, D. Graulich, and M. Dunz. Large exchange bias in polycrystalline MnN/CoFe bilayers at room temperature. Phys. Rev. B. 92(14), 144408 (2015).

MA 26.3 Tue 14:30 HSZ 101

Depth dependent magnetic structure of graded Co-alloy thin films — •Lorenzo Fallarino[1], Brian J. Kirby[2], Matteo Pancaldi[1], Patricia Riego[1], Casey W. Miller[3], Paolo Vavassori[1,4], and Andreas Berger[1] — [1]CIC nanoGUNE, Spain — [2]NCNR-NIST, USA — [3]RIT, USA — [4]IKERBASQUE, Spain

We present a study aimed at the precise tailoring of exchange coupling strength along the surface normal of sputter deposited Cobalt-Chromium ($Co_{1-x}Cr_x$) and Cobalt-Ruthenium ($Co_{1-x}Ru_x$) alloy thin films. We have grown a series of such compositionally graded epitaxial thin films, in which the Co content (1-x) has an overall bathtub-shaped profile along the surface normal. In addition to conventional magnetometry, temperature and field-dependent magnetic depth profiles have been measured by using polarized neutron reflectometry (PNR). The effective Curie temperature is found to vary as a function of depth, exhibiting a minimum in the center of the structure, which verifies the structurally and magnetically graded modulation. PNR also verified that the effective coupling in between the Co-rich outer layers is dependent on the magnetization of the central layer, and thus the overall magnetic reversal can be tuned continuously via temperature from a square hysteresis loop to a two-steps behavior. In addition, we have explored oscillatory Curie temperature structures of different wavelengths λ produced by a triangular Ru content profile, oscillating in between $x = 0.22$ and $x = 0.28$. By changing λ, we have investigated the possible length scales, in which compositional effects can be transferred into modulated magnetic states for such itinerant ferromagnets.

MA 26.4 Tue 14:45 HSZ 101

Topological Hall effect in antiferromagnetically coupled SrRuO3/La0.7Sr0.3MnO3 epitaxial heterostructures — •Ionela Lindfors-Vrejoiu[1] and Michael Ziese[2] — [1]II. Physikalisches Institut, Universität zu Köln, D-50937 Köln, Germany — [2]Institut für Experimentelle Physik II, Universität Leipzig, D-04103 Leipzig, Germany

The physical properties of epitaxial heterostructures and superlattices often show crucial differences to those of bulk compounds. Heterostructures of two prototypical ferromagnetic oxides, SrRuO3 and La0.7Sr0.3MnO3, exhibit a variety of novel intriguing phenomena, including the manifestation of a topological Hall effect. The novel features originate from the very different magneto-crystalline anisotropies of the two ferromagnets when grown as epitaxial layers, from an antiferromagnetic interlayer coupling that occurs via Mn-O-Ru bonds at the interfaces, and from the oxygen octahedral connectivity across the epitaxially coherent interfaces. The interplay between these results in a strongly non-collinear ordering of the Ru and Mn magnetic moments in the individual layers, which leads to the occurrence of a topological Hall effect.

MA 26.5 Tue 15:00 HSZ 101

Tunneling magnetoresistance on perpendicular CoFeB-based junctions with perpendicular exchange bias — •Orestis Manos, Alexander Boehnke, Robin Klett, Panagiota Bougiatioti, Karsten Rott, Alessia Niesen, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Department of Physics, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

Recently, magnetic tunnel junctions with perpendicular magnetized electrodes (pMTJs) combining perpendicular exchange bias (PEB) films have attracted considerable scientific interest. In this project, we fabricated and investigated the magneto-transport properties of the pMTJs stacks: Ta/Pd/IrMn/CoFe/Ta/Co-Fe-B/MgO/Co-Fe-B/A/Pd where A=Hf, Ta displaying PEB fields of 500 Oe [1] along with high PMA. From the magnetic loops is observed the noticeably higher PMA of the free layer for the Hf capped compared to the Ta capped CoFeB layer. Additionally, from the major tunnel magnetoresistance (TMR) loops at room temperature, we extract a value of equal to 50% and 40% in Hf and Ta capped stacks, respectively. The enhancement of PMA and TMR of Hf capped stack is attributed to the greater Boron absorbance of Hf compared to Ta [2-3]. Furthermore, for both samples is extracted the significantly enhanced TMR at low temperatures, reaching 105% at 10K for the sample with Hf as a capping layer.

[1] X. Zhang et al., IEEE Trans. Magn., 51, 11 (2015)
[2] A. Hindmarch et al., Appl. Phys. Express, 4, 013002 (2011)
[3] J. D. Burton et al., Appl. Phys. Lett., 89, 142507 (2006)

MA 26.6 Tue 15:15 HSZ 101

Control of the Néel vector orientation in Mn2Au thin films — •Alexey A. Sapozhnik[1,2], Radu Abrudan[3], Henning Huckfeldt[4], Alexander Gaul[4], Hartmut Zabel[1], Martin Jourdan[1], Mathias Kläui[1], and Hans-Joachim Elmers[1] — [1]Institute of Physics, JGU Mainz, Germany — [2]MAINZ Graduate School, Germany — [3]HZB, Germany — [4]Universität Kassel, Germany

Antiferromagnets (AFs) have the potential for ultrafast THz spin-dynamics and manipulation by, e.g., accessing the staggered magnetization along the Néel vector. The insensitivity to external magnetic fields has benefits. But new methods for controlling the AF domain state and direction of the Néel vector other than magnetic fields have to be invented. In this work, different methods of manipulating the Néel vector were investigated in Mn2Au, a high-Néel temperature metallic AF. X-ray magnetic linear dichroism (XMLD) spectroscopy measurements were performed at BESSY II to monitor the orientation of the Néel vector. A pulsed magnetic field of 70 T induces a spin-flop transition in Mn2Au and aligns the Mn moments generating a distinct XMLD effect. Absence of XMLD in an as-prepared reference sample confirms the magnetic origin of the dichroism. Helium ion bombardment reduces the Néel temperature of Mn2Au, enabling AF domain orientation in the exchange field of a ferromagnetic layer via field cooling. Mechanical tensile strain applied to Mn2Au thin films changes the crystal symmetry and orients the Néel vector perpendicular to the elongation direction. XMLD asymmetry in Mn2Au reaches a level of 0.4% upon application of 0.1% tensile strain.

MA 26.7 Tue 15:30 HSZ 101

Evolution of the local environment and magnetism in $Fe_{60}Al_{40}$ films under Ne^+ irradiation — •A. Smekhova[1,2], E. La Torre[2], B. Eggert[2], B. Cöster[2], Th. Szyjka[2], D. Walecki[2], S. Salamon[2], K. Ollefs[2,3], R. Bali[4], J. Lindner[4], A. Rogalev[3], E. Weschke[5], R. Banerjee[6], B. Sanyal[6], C. Schmitz-Antoniak[1], and H. Wende[2] — [1]FZ Juelich (PGI-6), Berlin — [2]University of Duisburg-Essen and CENIDE, Duisburg — [3]ESRF, Grenoble — [4]HZDR, Dresden — [5]HZB (BESSY II), Berlin — [6]Uppsala University, Uppsala

X-ray absorption spectroscopy has been applied to study the consequential changes of the local environment around Fe and its magnetic moments in $Fe_{60}Al_{40}$ thin films of 40 nm thickness along the order-disorder (B2 $\rightarrow$ A2) phase transition initiated by 20keV Ne^+ ion-irradiation with fluences of (0.75-6)$\times 10^{14}$ ions$\cdot$cm^{-2}. The analysis of EXAFS spectra measured at the Fe K-edge at room temperature revealed an increased number of Fe-Fe nearest-neighbors from 3.47(7) to 5.0(1) and $\sim$ 1% of volume expansion through the transition. The visualization of the Fe and Al nearest-neighbours rearrangement in the first coordination shell of Fe absorbers was done by wavelet transformations. The observed structural changes will be related to the magnetic properties of the studied samples. The results of self-consistent DFT calculations using VASP and SPR-KKR program packages on relaxed $Fe_{60}Al_{40}$ structures are consistent with the experimental findings for the ordered (B2) and the disordered (A2) phases.

MA 26.8 Tue 15:45 HSZ 101

ns-laser driven magnetic phase transition in FeAl — •Maciej Oskar Liedke[1], Rantej Bali[2], Elzbieta Gradauskaite[1], Jonathan Ehrler[2], Mao Wang[2], Kay Potzger[2], Shengqiang Zhou[2], and Andreas Wagner[1] — [1]Institute of Radiation Physics, HZDR, Dresden, Germany — [2]Institute of Ion Beam Physics and Materials Research, HZDR, Dresden, Germany

FeAl alloys show temperature dependent magnetic phase transition (MPT) from a ferromagnetic disordered A2-phase to a paramagnetic ordered B2-phase. The B2-phase can be reversed back to the A2-phase, e.g, by ion irradiation. The most plausible explanation of MPT points in direction of the anti-site disorder (ASD), i.e., more Fe-Fe nearest neighbors due to disordering. However, variations of the lattice parameter, defects concentration, and secondary phases may play an important role, too. Here, we employ an excimer UV ns-laser to examine the role of ASD and defects onto magnetic properties. Three sample series with different initial order conditions were irradiated by several laser fluences: (i) as-grown semi-, (ii) Ne irradiated fully-disordered, and (iii) vacuum annealed ordered alloys. Two magnetic regimes were found depending on laser fluence: (i) in the low fluence range magnetization initially decreases, followed by (ii) subsequent monotonic increase for larger fluences. The positron annihilation spectroscopy measurements reveal changes of defects surrounding from Al- to Fe-dominant, respectively, as well as of defects concentration. The results obtained by MOKE, VSM, AFM, and TEM will be discussed in detail.

MA 27: Spintronics (incl. Quantum Dynamics)

Time: Tuesday 14:00–15:45 Location: HSZ 301

MA 27.1 Tue 14:00 HSZ 301

Prediction of an intrinsic spin Hall effect without spin-orbit coupling in non-collinear antiferromagnets — •Yang Zhang[1,2], Jakub Zelezny[1], Jeroen van den Brink[2], Claudia Felser[1], and Binghai Yan[1,3] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [3]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden,Germany

The spin Hall effect (SHE), which converts a charge current into a transverse spin current, has long been believed to be a phenomenon induced by the spin-orbit coupling. In this work, we have revealed the existence of an intrinsic SHE without the spin-orbit coupling by theoretical calculations. Such a SHE is realised in the chiral spin structure of non-collinear antiferromagnets, even when the scalar spin chirality is zero. We have obtained large intrinsic spin Hall conductivity in related compounds Mn 3 Ge and Mn 3 Sn, that are chiral antiferromagnetic above room temperature and also predicted to be Weyl semimetals recently. Our work provides further understanding on the spin Hall effect and paves a new way to design SHE materials based on the chiral magnetic materials.

MA 27.2 Tue 14:15 HSZ 301

Ising spintronics in transition-metal dichalcognides — •Bin Shao[1], Malte Schüler[1,2], Gunnar Schönhoff[1,2], Thomas Frauenheim[1], Gerd Czycholl[2], and Tim Wehling[1,2] — [1]Bremen Center for Computational Materials Science, Universität Bremen, Am Fallturm 1a, 28359 Bremen, Germany — [2]Institut für Theoretische Physik, Universität Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

The orbital character of charge carriers at the Fermi level of transition-metal dichalcognides, MX_2 (M = Mo, W; X = S, Se, Te), can be selected via doping levels, leading to orbital dependent spin-flip scatterings with magnetic adatoms on MX_2. By utilizing this feature, we propose a mechanism for Ising spintronics relying on the tunability of spin lifetime of transition-metal adatoms with d^9 configuration on a MX_2 monolayer. The spin lifetime can be tuned by more than two orders by shifting the Fermi level only slightly. Moreover, the system exhibits a sizable magnetic anisotropy. We calculate the spin lifetime and magnetic anisotropy of magnetic adatoms based on an effective model Hamiltonian, reveling their connections to doping levels and the symmetry of adsorption sites straightforwardly. Our *ab initio* calculations suggest that this Ising-type spintronics should be realizable in Co, Rh, or Ir adatoms on MoS_2.

MA 27.3 Tue 14:30 HSZ 301

A three-input majority gate with chiral magnetic solitons — Konstantinos Koumpouras[1], Dmitry Yudin[2], Danny Thonig[1], Christoph Adelmann[3], Anders Bergman[1], Olle Eriksson[1], and •Manuel Pereiro[1] — [1]Department of Physics and Astronomy, University Uppsala, Sweden — [2]ITMO University, Saint Petersburg 197101, Russia — [3]IMEC vzw. Kapeldreef 75, B-3001 Leuven, Belgium

In magnetic materials, nontrivial spin textures may emerge owing to the competition among different types of magnetic interactions. In particular, chiral magnetic solitons, represent topologically protected spin configuration with particle-like properties, that are ideally suited to perform logical operations. Based on atomistic spin dynamics simulations, we propose to make use of magnetic solitons in a functional and dynamic three-input majority gate, in which the input states can be controlled by applying an external electromagnetic field or spin-polarized currents. One of the main advantages of the proposed device is that the input and output signals are encoded in the chirality of solitons, allowing to perform logical operations. As examples we illustrate how the proposed device can be used to perform logical relations such as Boolean AND and OR.

MA 27.4 Tue 14:45 HSZ 301

Spin-torque Effects in Thermally Assisted Magnetization Reversal: Kramers' Escape Rate Theory Approach — Yuri P. Kalmykov[1], Declan J. Byrne[2], •William T. Coffey[3], William J. Dowling[3], Sergey V. Titov[4], and Jean Eric Wegrowe[5] — [1]Univ. Perpignan Via Domitia, Laboratoire de Mathématiques et Physique, F-66860, Perpignan, France — [2]School of Physics, University College Dublin, Belfield, Dublin 4, Ireland — [3]Department of Electronic and Electrical Engineering, Trinity College, Dublin 2, Ireland — [4]Kotel'nikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Vvedenskii Square 1, Fryazino, Moscow Region, 141120, Russia — [5]Laboratoire des Solides Irradiés, Ecole Polytechnique, 91128 Palaiseau Cedex, France

Thermal fluctuations of nanomagnets driven by spin-polarized currents are treated via the Landau-Lifshitz-Gilbert equation generalized to include both the random thermal noise field and the Slonczewski spin-transfer torque (STT) term. The reversal time of the magnetization in such a nanomagnet are evaluated for wide ranges of damping by using the method of Coffey et al. [Phys. Rev. E 63, 021102 (2001)]. Their method generalizes the Mel'nikov-Meshkov approach [J. Chem. Phys. 85, 1018 (1986)] for bridging the very low damping (VLD) and intermediate damping (ID) Kramers escape rates for mechanical Brownian particles (the Kramers turnover problem) to the analogous magnetic turnover problem.

MA 27.5 Tue 15:00 HSZ 301

Inducing spin in semiconducting 2D phosphorene — •Mukul Kabir — Department of Physics, and Centre for Energy Science, Indian Institute of Science Education and Research, Pune, India

Inducing magnetic moment in otherwise nonmagnetic two-dimensional semiconducting materials is the key first step to design spintronic materials. In this talk, we will address the feasibility of inducing such local moment in single-layer phosphorene through 3d transition-metal (TM) doping without affecting its intrinsic semiconducting nature. While adjudicating on this subject, all previous studies conveniently neglected TM diffusion. However, we predict that increased TM diffusivity on pristine phosphorene would severely hinder any possibility of controlled magnetism, and thus any application. Here we propose that the point-defects will anchor metals, and exponentially reduce the diffusivity. We further argue that the divacancy complex is imperative in any practical purpose due to their increased thermodynamic stability over monovacancy. For most cases, the defect-transition metal complexes retain the intrinsic semiconducting properties, and also induce a local magnetic moment with large exchange-splitting and spin-flip energies, which are necessary for spintronic applications. Further, we provide a simple microscopic model to describe the local moment formation in these transition metal and defect complexes. Moreover, such metal absorption could completely alter the intrinsic electronic structure of the single-layer phosphorene, and may lead to exotic many-body physics.

MA 27.6 Tue 15:15 HSZ 301

Adsorption and element-specific detection of transition metal porphyrins by spin-dependent conductance of a graphene nanoribbon — •Peter Kratzer[1], Sherif A. Tawfik[2], Xiang Yuan Cui[2], and Catherine Stampfl[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]The University of Sydney, Sydney, New South Wales 2006, Australia

Transition metal porphyrins, their adsorption on graphene nanoribbons (GNRs), and its consequences for electronic transport through the GNRs are investigated by means of density functional theory calculations. Interaction with a single-atom vacancy in the GNR is found

to be a prerequisite for chemical bonding of the transition metal centre. In both the physisorbed and the chemisorbed geometry, the inclusion of van der Waals interaction results in a significant enlargement of the binding energy. Electronic transport calculations using non-equilibrium Greens functions show that the conductivity of the edge states in the GNR is altered by the chemisorbed porphyrin molecules. Since the metal centers of porphyrins carry an element-specific magnetic moment, the spin-dependence of the conductance of the GNR is altered, too. In particular, the adsorption of Ru-porphyrin or Fe-porphyrin on the single-atom vacancy results in a large spin polarization of the current of 88% and -62%, respectively, at small applied source-drain voltages. Based on our results, we suggest that a spin valve constructed from a GNR with ferromagnetic contacts could be used as a sensitive detector that could discriminate between various metal porphyrins.

MA 27.7 Tue 15:30 HSZ 301

Shape Memory Alloys in Hybrid Spintronic Devices — •Andreas Becker and Andreas Hütten — Bielefeld University, Bielefeld, Germany

Observations of the phase transition in ferromagnetic shape memory alloys (FSMAs) by x-ray diffraction and magnetization measurements are reported frequently. Our goal is to investigate the phase transformation by using the tunnel magnetoresistance effect (TMR), thus FSMAs are utilized either as ferromagnetic electrodes (Ni50-xCoxMn30Al20/MgO/ Co40Fe40B20) or as an underlying layer beneath the magnetic tunnel junction (Ni50-xCoxMn30Al20/ Co40Fe40B20/MgO/ Co40Fe40B20).

The off-stoichiometric Ni50-xCoxMn30Al20 thin films are grown by sputter deposition and patterned by e-beam lithography. X-ray diffraction measurements indicate a B2 crystal structure. An untypical change in the TMR amplitude is observed in tunnel junctions on top of the Heusler alloy upon heating the sample. We suggest that this phenomenon arises from the induced strain of the reverse martensitic transformation. Furthermore the FSMA will act as a ferromagnetic electrode if the magnetic properties are enhanced by substituting Ni with Co atoms. At x=10 a TMR of about 2.5% at room temperature and 6% at 10 K is measured in Ni50-xCoxMn30Al20 /MgO/Co40Fe40B20 tunnel junctions while no TMR is found over the measured temperature range in samples with x=4.

MA 28: Spin Dynamics and Transport: Domain Walls

Time: Tuesday 14:00–15:45 Location: HSZ 401

MA 28.1 Tue 14:00 HSZ 401

Inertia-Free Thermally Driven Domain-Wall Motion in Antiferromagnets — •Severin Selzer[1], Unai Atxitia[1], Ulrike Ritzmann[2], Denise Hinzke[1], and Ulrich Nowak[1] — [1]Universität Konstanz — [2]Johannes Gutenberg-Universität Mainz

Induced domain wall motion is the key to an efficient and fast control of magnetic nanostructures. Due to their complex spin structures leading to higher spin dynamics than in ferromagnets, antiferromagnets are promising candidates as materials for future devices.

Domain-wall motion in antiferromagnets triggered by thermally induced magnonic spin currents is studied theoretically. It is shown by numerical calculations based on a classical spin model that the wall moves towards the hotter regions, as in ferromagnets. However, for larger driving forces the so-called Walker breakdown - which usually speeds down the wall - is missing. This is due to the fact that the wall is not tilted during its motion. For the same reason antiferromagnetic walls have no inertia and, hence, no acceleration phase leading to higher effective mobility (Phys. Rev. Lett. 117, 107201).

MA 28.2 Tue 14:15 HSZ 401

Chiral domain walls in low dimensional Co heterostructures — •Jonathan Chico[1], Konstantinos Koumpouras[2], Lars Bergqvist[3,4], and Anders Bergman[2] — [1]Peter Grünberg Institut and Institute of Advanced Simulation, Forschungszentrum Jülich & JARA, D-52428, Jülich, Germany — [2]Department of Physics and Astronomy, Materials Theory Division, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [3]Department of Materials and Nano Physics, School of Information and Communication Technology, KTH Royal Institute of Technology, Electrum 229, SE-16440 Kista, Sweden — [4]SeRC (Swedish e-Science Research Center), KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden

Recently relativistic effects in domain wall dynamics have come to the forefront in ultra thin magnetic layers in contact with heavy metals, where domain wall motion against the electron flow has been observed, phenomena which cannot be explained only by the volume spin transfer torque (STT)[1].

From the first principles point of view we investigate Co thin films in contact with substrates composed of 4d and 5d elements. The substrate is observed to play a major role in the magnetocrystalline anisotropy and the Dzyaloshinskii-Moriya interactions (DMI). Atomistic spin dynamics simulations making use of these parameters, showcase how the chiral nature of the domain walls present in these systems, in combination with the Spin Hall Effect, can describe the recent experimental findings.

[1] Kwang-Su Ryu et. al *Nature Nanotech.*, **8**, 527 (2013)

MA 28.3 Tue 14:30 HSZ 401

Efficient Current Induced Motion of Chiral Domain Walls — Robin Bläing[1], •Tianping Ma[1], Chirag Garg[1,2], Tom Lichtenberg[1], See-Hun Yang[2], Ilya Kostanovskiy[1], and Stuart Parkin[1,2] — [1]Max Planck Institut of Microstructure Physics, Halle, Germany — [2]IBM Almaden Research Center, San Jose, US

Novel three-dimensional memory devices based on magnetic domains in thin film ferromagnets have high potential to solve long-term memory storing problems. One example is the racetrack memory which is based on current-induced motion of the magnetic domains. The driving force is a spin current injected into the ferromagnetic layer from an underlayer via the spin Hall effect. In addition, the Dzyaloshinskii-Moriya interaction plays a major role in order to achieve an efficient motion. We study novel 2D materials to improve the spin Hall efficiency and Dzyaloshinskii-Moriya interaction. Furthermore, for commercial devices the threshold current to efficiently drive magnetic domain walls needs to be lowered and therefore temperature dependent measurements are performed to gain further understanding of this property.

MA 28.4 Tue 14:45 HSZ 401

Anticlockwise Néel domain walls in ultrathin Cobalt films on Pt(111) — Edna Corredor Vega, •Susanne Kuhrau, Fabian Kloodt, Robert Frömter, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

Recently, the Co/Pt (111) system has attracted large interest because of the potential to stabilize isolated skyrmions at room temperature (RT) due to its large interfacial Dzyaloshinskii-Moriya Interaction (DMI). We present a comprehensive study on Co wedges epitaxially grown on Pt (111) at RT with thicknesses ranging between 0 to 7 ML. The magnetic microstructure is investigated via Scanning Electron Microscopy with Polarization Analysis (SEMPA) [1]. The SEMPA is designed to image the in-plane components of the magnetization. For the investigation the sample was slightly tilted to get access to the perpendicular component. On increase of Co thickness the domain size shrinks. In the thickness range studied all domain walls are of Néel type and show a fixed sense of rotation. For 7 ML the wall width is (10.8±1.3) nm. A lower limit estimate of the DMI vector D [2] reveals a value of $D > 1$ mJ/m^2 for 7 ML.

[1] R. Frömter, et al., Rev. Sci. Instrum. 82, 033704, (2011).
[2] A. Thiaville, et al. Europhys. Lett. 100, 57002 (2012).

MA 28.5 Tue 15:00 HSZ 401

Domain width model for perpendicularly magnetized systems including DMI — •Thomas N.G. Meier, Matthias Kronseder, and Christian H. Back — Institut für experimentelle und angewandte Physik, Universität Regensburg, Deutschland

In ultrathin ferromagnetic films with perpendicular anisotropy a spin-reorientation transition from out-of-plane to in-plane orientation of the magnetization vector may occur. The competition of exchange and anisotropy energy on the one hand and the dipole interaction on the other hand leads to the formation of stripe domain patterns in the vicinity of the spin reorientation transition. Recently a strong

Dzyaloshinskii-Moriya interaction (DMI) was found in various perpendicularly magnetized multilayer systems due to symmetry breaking at interfaces. The dependence of the stripe domain width on the DMI is theoretically and experimentally investigated. A domain spacing model applicable in the normal stripe domain phase is developed describing the dependence of the stripe domain width on the magnetic properties of the sample. We present a new approach to determine the magnitude of the DMI-constant by fitting the stripe domain width as a function of the effective perpendicular anisotropy on wedge-shaped samples with the model. By applying this method to the domain pattern of several ultrathin multilayer samples based on Ni/Fe/Cu(001) imaged by TP-MCD-PEEM the magnitude of the DMI of the FeNi- and NiFe-interfaces is determined. Furthermore we show that the DMI in Ni/Fe/Cu(001) can be considerably enhanced by adding an overlayer of platinum to the sample stack.

MA 28.6 Tue 15:15 HSZ 401

Current-driven periodic domain wall creation in ferromagnetic nanowires — •Matthias Sitte[1], Karin Everschor-Sitte[1], Thierry Valet[1], Davi R. Rodrigues[2], Jairo Sinova[1,3], and Artem Abanov[2] — [1]Institute of Physics, Johannes Gutenberg-Universität, 55128 Mainz, Germany — [2]Department of Physics & Astronomy, Texas A&M University, College Station, Texas 77843-4242, USA — [3]Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnicka 10, 162 53 Praha 6, Czech Republic

We predict the electrical generation and injection of domain walls into a ferromagnetic nanowire without the need of an assisting magnetic field. Our analytical and numerical results show that above a critical current j_c domain walls are injected into the nanowire with a period $T \sim (j - j_c)^{-1/2}$. Importantly, domain walls can be produced periodically even in a simple exchange ferromagnet with uniaxial anisotropy, without requiring any standard "twisting" interaction such as Dzyaloshinskii-Moriya or dipole-dipole interactions. We show analytically that this process and the period exponents are universal and do not depend on the peculiarities of the microscopic Hamiltonian. Finally we give a specific proposal for an experimental realization.

MA 28.7 Tue 15:30 HSZ 401

Magnetism and Transport in Hybrid Magnetic Nanowires — •Sergej Andreev, Roman Hartmann, and Torsten Pietsch — Universität Konstanz, Deutschland

Ensembles of magnetic nanowires are the core-elements of various applications in nonvolatile memories, microwave devices and communication technologies as well as humidity- and gas sensors. Moreover, due to their small diameter in the range of few to tens of nanometers, these systems are highly interesting in magnonics and spin-(transfer) electronics, where high spin-current are required. Here we show how well-defined ensembles of hybrid, magnetic nanowires with diameters of few tens of nm, composed of multilayers of ferromagnetic Ni, NiCu, Co and other non-magnetic metals can be grown in microstructured arrays and integrated in high-frequency microwave electronic devices. The collective static and dynamic magnetic properties of the nanowire arrays are evaluated via SQUID magnetometry and FMR /EPR measurements. Additionally we will outline the potential of these devices in microwave- and THz emitters as well as spin-transfer driven magnetic oscillators.

MA 29: Spin dependent Transport Phenomena

Time: Tuesday 14:00–15:15 Location: HSZ 403

MA 29.1 Tue 14:00 HSZ 403

Ab initio calculations of bias voltage dependence of magneto crystalline anisotropy in magnetic tunnel junctions — •Christian Heiliger, Carsten Mahr, and Michael Czerner — Institute for Theoretical Physics, Justus Liebig University Giessen, Germany

Spin-orbit effects play an important role in current spintronics research. One effect due to spin-orbit coupling is the magneto crystalline anisotropy (MCA) and the control of this effect by a bias voltage. Using density functional theory in combination with non-equilibrium Green's function method we calculate the bias voltage dependence of MCA for the case of a V/Fe/MgO/V. We discuss the dependence of MCA and of the tunneling anisotropic magneto resistance (TAMR) on the Fe and MgO slab thicknesses. Further, we show the voltage dependence of spin-torque originated in these tunnel junctions and clarify the connection to the MCA. All our results are compared to recent experimental results in the same junctions.

MA 29.2 Tue 14:15 HSZ 403

Planar Hall effect in Au/Fe/MgO (001) heterostructures for spin-orbitronics — •Pika Gospodaric[1], Ewa Mlynczak[1], Daniel E. Bürgler[1], Frank Volmer[2], Bernd Beschoten[2], Lukasz Plucinski[1], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]2nd Institute of Physics and JARA-FIT, RWTH Aachen University, 52074 Aachen, Germany

The combined effects of the spin-orbit coupling (SOC) and the exchange interaction can generate torques acting on the magnetization of a ferromagnet. Strong SOC can be achieved in a ferromagnetic metal (FMM) by close proximity to a heavy metal (HM). Recently, it was shown that by applying a current in the plane of a FMM, sandwiched between a HM and an oxide layer, the magnetization of the FMM layer can be manipulated. This phenomenon is now known as the spin-orbit torque (SOT) and is explained either on the basis of the Rashba field present at the interface of the layers or a strong spin Hall effect in the HM layer. In this contribution we present the observation of changes of the magnetization direction of a prototypical FMM, namely an Fe (001) thin film in epitaxially grown Au/Fe/MgO (001) heterostructures. We identified a four-fold in-plane magnetic anisotropy of the Fe (001) layer with magneto-transport measurements and detected changes of the magnetization direction using the planar Hall effect. Above a critical current threshold of 2 x 10^7 A/cm^2 we measured an increase of the induced Hall voltage, which we attribute to a SOT-induced tilt of the magnetization direction of the Fe (001) layer.

MA 29.3 Tue 14:30 HSZ 403

Ab initio calculation of thermal dependent anomalous Hall effect — •David Wagenknecht, Karel Carva, and Ilja Turek — Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Anomalous Hall effect (AHE) is directly connected to nondiagonal elements of the electrical conductivity tensor. Therefore, it is an important phenomenon bringing fundamental information about solid materials. A large change in the AHE may be used, e.g., to define a binary information leading to a construction and switching of antiferromagnetic structures like memories [1]. Thus, the knowledge of the AHE is essential at the room temperatures, where the devices should operate.

We have calculated electrical transport properties including the AHE from the first principles and incorporated thermal disorder. Fully relativistic linear muffin-tin orbital (LMTO) approach with the coherent potential approximation (CPA) was used [2] and the effect of non-zero temperature was described by a frozen lattice displacements [3]. Nickel and simple nickel-based alloys (nonstochiometric $Cu_{1-x}Ni_x$ and $Co_{1-x}Ni_x$) were used to verify our approach that may now be applied to more complex materials (semi-Heusler NiMnSb, antiferromagnet CuMnAs, ...).

[1] N. Kiyohara et al. Phys. Rev. Applied 5, 064009 (2016)
[2] K. Carva et al. Phys. Rev. B 73, 144421 (2006)
[3] D. Wagenknecht et al. In Šafránková, Jana; Pavlů, Jiří. WDS'15 Proceedings of Contributed Papers - Physics. : Matfyzpress (2015). s. 42*47. ISBN 978-80-7378-311-2.

MA 29.4 Tue 14:45 HSZ 403

Nonlocal anomalous Hall effect in ternary alloys — •Franziska Töpler[1], Albert Hönemann[1], Katarina Tauber[1], Dmitry Fedorov[2,1], Martin Gradhand[3], Ingrid Mertig[1,2], and Albert Fert[4] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]University of Bristol, Bristol, United Kingdom — [4]Université Paris-Sud, Université Paris-Saclay, Paris, France

The spin Hall effect (SHE) [1] and the anomalous Hall effect (AHE) [2] are two promising phenomena for novel spintronic devices. Authors of Ref. [3] proposed to enhance the AHE in noble metal hosts with magnetic 3*d* impurities by codoping of heavy nonmagnetic impurities.

We present a detailed study [4] of the transverse charge transport in such ternary alloys related to the so-called *nonlocal* AHE, recently introduced [5]. The results of our *ab initio* calculations are underpinned and explained by theoretical investigations via Matthiessen's rule. Considering transport properties of the constituent binary alloys, we reveal optimal host-impurity combinations to enhance the AHE. This allows us to explain experimental findings [3] showing a strong effect in Cu-based alloys but a vanishing effect in the case of the Au host.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015)
[2] Nagaosa *et al.*, Rev. Mod. Phys. **82**, 1539 (2010)
[3] Fert *et al.*, J. Magn. Magn. Mater. **24**, 231 (1981)
[4] Töpler *et al.*, Phys. Rev. B **94**, 140413(R) (2016)
[5] Zhang and Vignale, Phys. Rev. Lett. **116**, 136601 (2016)

MA 29.5 Tue 15:00 HSZ 403

Exchange and spin-orbit induced phenomena in diluted (Ga,Mn)As from first principles — •Josef Kudrnovsky[1], Vaclav Drchal[1], and Ilja Turek[2] — [1]Institute of Physics AS CR, Prague, Czech Republic — [2]Institute of Physics of Materials AS CR, Brno, Czech Republic

Physical properties induced by exchange interactions (Curie temperature and spin stiffness) and spin-orbit coupling (anomalous Hall effect, anisotropic magnetoresistance, and Gilbert damping) in the diluted (Ga,Mn)As ferromagnetic semiconductor are studied from first principles. Recently developed Kubo-Bastin transport theory and nonlocal torque operator formulation of the Gilbert damping as formulated in the tight-binding linear muffin-tin orbital method are used. The first-principles Liechtenstein mapping is employed to construct effective Heisenberg Hamiltonian and to estimate Curie temperature and spin stiffness in the real-space random-phase approximation which takes into account the effect of magnetic percolation. Good agreement of calculated physical quantities with experiments for well-annealed samples containing only a small amount of compensating defects is obtained. Their possible effect will be briefly discussed.

MA 30: Electronic structure of Surfaces: Magnetism and Spin Phenomena

Time: Tuesday 18:30–20:30 Location: P1A

MA 30.1 Tue 18:30 P1A

A silicon-based room temperature spin source without magnetic layers — •Debkumar Bhowmick, Matthias Kettner, Manfred Bartsch, and Helmut Zacharias — Physikalisches Institut, WWU Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

Controlling the electron spin orientation and spin injection into functional electronic devices is of central importance in the field of spin transport electronics or spintronics. So far ferromagnetic metal/semiconductor junctions have been used to develop for spintronics which works only under low-temperature. Self-assemble chiral molecular monolayer (like dsDNA, Lysine) on gold shows promising in the direction of development of room temperature spintronic devices. In this present study, electron spin filtering by DNA on silicon, covalently bound by a 3-isothiocyanatopropyl triethoxy silane linker have been shown. This provides a means for developing room temperature spintronics. Electrons from silicon passing through double-stranded DNA acquire a longitudinal spin polarization. This enables the integration of helical molecules as spin filters in modern electronics for spin control, injection, and detection.

MA 30.2 Tue 18:30 P1A

A Riccati equation based model for chiral spin filters — •Daniel Nürenberg, Matthias Kettner, and Helmut Zacharias — Physikalisches Institut, Uni Münster, Germany

The spin selective transport of electrons in chiral molecules is currently under intense research in theory and experiment. These experiments include studies of the dependence of the spin polarization on the length of the molecules and on the starting spin polarization from the substrate. We show that the evolution of the spin polarization of an ensemble of electrons during propagation can be described by a Riccati equation, which can be fitted to experimental data. We propose that the coefficients in this model are suitable to characterize the efficiency of spin filters and help to distinguish spin-flip and perturbation from spin-dependent extinction effects. These perturbations also limit the spin polarization for long molecules. We apply our model to fit previous experimental data from DNA, oligopeptides and [7]-helicene.

MA 30.3 Tue 18:30 P1A

Enantiomer-dependency of spin orientation in photoelectron transmission through heptahelicene — •Matthias Kettner[1], Daniel Nürenberg[1], Johannes Seibel[2], Karl-Heinz Ernst[2], and Helmut Zacharias[1] — [1]Physics Institute und Center for Soft Nanoscience, University of Münster, Germany — [2]Nanoscale Materials Science, EMPA, Switzerland

Spin transport electronics (spintronics) enables a new generation of efficient electronic and non-volatile memory devices. Though the concept of spintronics is well known, the field still lacks devices that work under ambient conditions. Experiments on self-assembled monolayers of double stranded DNA [1,2] and oligopeptides [3] indicated a very efficient spin filtering behavior of the molecules at room temperature. In present experiments enantiopure M- and P-heptahelicene molecules are evaporated onto noble metal single crystal surfaces. The molecules arrange themselves to a highly ordered monolayer [4]. Samples are then irradiated with $\lambda = 213\,\mathrm{nm}$ laser radiation to generate photoelectrons from the substrate. These electrons are transmitted through the heptahelicene layer and analyzed with regard to their average longitudinal spin orientation by a Mott polarimeter. The sign of the spin polarization is related to the helicity of the enantiomer whereas an influence of substrate on the spin-filter effect has not been observed.

[1] Göhler, B. et al., Science 2011, 331, 894. [2] Kettner, M. et al., Adv. Mater. Interfaces, 2016, 3, 1600595. [3] Kettner, M. et al., J. Phys. Chem. C 2014, 119, 26. [4] Ernst, K.-H., Acc. Chem. Res. 2016, 49, 1182.

MA 30.4 Tue 18:30 P1A

Laser induced photocurrents in a Topological Insulator thin film analyzed by 2D maps for VIS and NIR — •Thomas Schumann[1], Helena Reichlová[3], Gregor Mussler[4], Eva Schmoranzerová[2], Pertr Němec[2], Tobias Kampfrath[5], Christian Heiliger[6], and Markus Münzenberg[1] — [1]IfP, University of Greifswald, Germany — [2]MFF, Charles University, Prague, Czech Republic — [3]FZU, Prague, Czech Republic — [4]PGI-9, Jülich, Germany — [5]FHI Berlin, Germany — [6]University of Gießen, Germany

Topological Insulators (TI) open up a new route to influence the transport of charge and spin in a surface film via spin-momentum locking [1,2]. It has been demonstrated experimentally [2] that illumination by circularly polarized light can result in excitation of a helicity-dependent photocurrent. We report our recent results on laser induced photocurrents in a terniary 3D TI thin film. The resulting photocurrents have been studied by 2D photocurrent maps for different dopings and for VIS to NIR laser excitation. We although discuss the effects of contacts and edges if they are illuminated by the laser.

[1]S.D.Ganichev,W.Prettl,J.Phys.: Condens. Matter 15 (2003) R935-R983
[2]J.W.McIver,D.Hsieh,H.Steinberg,P.Jarillo-Herrero and N.Gedik, Nature Nanotechnology 7, 96-100 (2012)

We acknowledge the funding of the DFG via the SPP 1666 Topological Insulators and the joint DAAD PPP Czech Republic project FemtomagTopo.

MA 30.5 Tue 18:30 P1A

Inelastic Excitations on Fe-TPyP on Au(111) — •Daniela Rolf, Christian Lotze, Benjamin W. Heinrich, and Katharina J. Franke — Freie Universität Berlin

Prophyrin molecules constitute a class of well-investigated molecules, due to their versatility in terms of self-assembly and electronic and magnetic properties. Numerous studies have been performed with different central metal atoms on different metal surfaces, showing that by a suitable choice of metal center and surface, the molecular properties can be tailored. Interesting phenomena were observed, including the Kondo effect, vibronic coupling and negative-differential resistance.

Here, Fe-tetra-pyridil-porphyrin (Fe-TPyP) molecules were investigated on a Au(111) substrate. Employing a low-temperature STM, we show that a multitude of steps in the dI/dV-signal up to 135meV can be observed symmetrically around the Fermi level. These inelastic excitations were observed both on the Fe-center of the molecule as well as on the organic TPyP ligand, with some of the steps on the ligand being visible only at positive bias polarity. As none of the inelastic excitations could be observed on chlorine-coordinated Fe-TPyP-Cl molecules, molecular vibrations were excluded as the origin of the inelastic excitations. Instead, a contribution of magnetic origin is assumed.

MA 30.6 Tue 18:30 P1A

Yu-Shiba-Rusinov states and inelastic excitations in Iron Porphine molecules on Pb(111) — •Laëtitia Farinacci, Gaël Reecht, Benjamin W. Heinrich, and Katharina J. Franke — Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

When adsorbed on a superconductor, magnetic impurities couple to the quasi-particles of the substrate. This interaction induces Yu-Shiba-Rusinov (YSR) states within the BCS gap of the superconductor whose energy depends on the coupling strength. In case of a vanishing coupling, they merge with the gap edge and it may be possible to observe inelastic excitations outside of the BCS gap.

Using STM we investigate the properties of Iron Porphine molecules on a Pb(111) surface. After deposition, the molecules form islands with a hexagonal pattern. Within these islands, two different types of molecules can be identified. Type I molecules show a clover shape with a central protrusion while type II molecules have a square-like appearance. YSR states are observed above type I molecules. Depending on their surroundings type II molecules can display inelastic excitations outside the BCS gap of Pb(111).

By approaching the tip closer to the molecules we are able to tune the energies of these YSR states and inelastic excitations. In particular, the YSR states can be suppressed.

MA 30.7 Tue 18:30 P1A

Investigation of Ferromagnetism on Graphite due to Swift Heavy Ion Irradiation — •Eren Güvenilir[1], Cem Kincal[1], Umut Kamber[1], Dilek Yildiz[1,2], Clara Grygiel[3], Cornelis J. Van Der Beek[4], and Oğuzhan Gürlü[1] — [1]Istanbul Technical University, Istanbul, Turkey — [2]University of Basel, Basel, Switzerland — [3]Universite de Caen, Caen, France — [4]Ecole Polytechnique, Palaiseau

Defect induced ferromagnetism have been reported on carbon based materials. In this work we investigated the magnetic properties of highly ordered pyrolytic graphite (HOPG) samples after irradiation with swift heavy ions (SHI). Samples were irradiated under 80° and 87.5° angle of incidence using highly charged and highly energetic Pb and U ions. Such SHI irradiation generates comet-like defects on the sample surfaces. We performed magnetic force microscopy under atmospheric ambient conditions. Our measurements revealed that comet-like defects caused by SHI irradiation have significantly higher magnetic signal compared to native defects on HOPG surfaces.

MA 30.8 Tue 18:30 P1A

Spin-resolved electron transmission through self-assembled layers of PNA — •Paul Möllers[1], Matthias Kettner[1], Daniel Nürenberg[1], Francesco Tassinari[2], Tal Z. Markus[2], Catalina Achim[3], Ron Naaman[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, Universität Münster, Germany — [2]Department of Chemical Physics, Weizmann Institute, Rehovot, Israel — [3]Department of Chemistry, Carnegie Mellon University, Pittsburgh, Pennsylvania, United States

The yield of electrons transmitted through chiral molecules can depend on the electron's spin; chiral molecules can therefore act a spin filters. This effect is referred to as the chirality-induced spin selectivity (CISS). Previous experiments have e.g. been performed with monolayers of double-stranded DNA [1]. In this contribution, we present results of our spin-resolved photoemission experiments performed at room temperature. The samples consist of self-assembled monolayers of helical molecules – various types of double-stranded peptide nucleic acid (PNA) – on polycrystalline gold surfaces. The samples are irradiated by a laser at $\lambda = 213\,\mathrm{nm}$ to generate photoelectrons from the gold substrate which are then transmitted through the adsorbed monolayer. Subsequently, the electrons are analyzed by a Mott polarimeter. We found longitudinal spin polarizations of $-5\,\%$ for PNA and $+4\,\%$ for γ-PNA. The results indicate that the adsorbed molecules act as a spin filter.

[1] B. Göhler et al., Science 331, 894 (2011)

MA 31: Ultrafast Electron and Spin Dynamics

Time: Tuesday 18:30–20:30 Location: P2-EG

MA 31.1 Tue 18:30 P2-EG

Excited Electron Dynamics in Thiophene-based Polymers — •Carsten Winter, Deb Kumar Bhowmick, Nils Fabian Kleimeier, and Helmut Zacharias — Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

Optically active thiophene-based polymers are promising candidates for solar cell, OLED or transistor applications. Several variants of thiophene polymers coupled with pyrrole or fluorene chains exist, and form an internal donor-acceptor system.

In this presentation we show the results of a time-dependent photoemission study on the three thiophene polymers PFTT (with a fluorene extension), PDPP4T and DTT (with a pyrrole extension) on a Si(100) substrate. The fundamental, second and third harmonics of a 6 kHz, 35 fs Ti:Sapphire laser system with a time-of-flight spectrometer are utilized for static 3PPE to determine the energetic positions of high lying occupied and intermediate unoccupied electronic levels. Dynamic 3PPE is then used to study the electron dynamics of the intermediate states directly in the time domain.

One-color 3PPE with 3 eV on PFTT shows intermediate lifetimes of 65 to 195 fs depending on the electron kinetic energy and the order of p- and s-pulse. On PDPP4T and DTT a two-color experiment (1.5 eV and 4.5 eV) can determine two distinct, longer electronic lifetimes between 1 and 10 ps for the faster channel and 20 to 100 ps for the slower channel.

MA 31.2 Tue 18:30 P2-EG

Ultrafast Doublon Dynamics in $1T$-TaS$_2$ — •Manuel Ligges[1], Isabella Avigo[1], Denis Goleš[2], Matthias Kalläne[3], Kai Rossnagel[3], Martin Eckstein[4], Phillip Werner[2], and Uwe Bovensiepen[1] — [1]Faculty of Physics, Universität Duisburg-Essen — [2]Department of Physics, University of Fribourg, 1700 Fribourg, Switzerland — [3]Institute of Experimental and Applied Physics, Universität Kiel, 24098 Kiel — [4]Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, 22761 Hamburg

Using time- and angle-resolved photoemission we study photo-induced electron dynamics in the (quasi-)2D Mott insulator $1T$-TaS$_2$. In the low excitation limit, we observe population and subsequent decay dynamics of the upper Hubbard band that are significantly faster than expected, indicating a characteristic time scale of $\hbar/J$ for the underlying scattering processes. Theoretical calculations based on dynamic mean field theory indicate that such dynamics only occur when the system is effectively hole-doped. We furthermore stress that on these time scales the electronic and phononic subsystems are decoupled.

MA 31.3 Tue 18:30 P2-EG

Ultrafast electron dynamics in single crystals studied by time-resolved two-photon momentum microscopy — •Tobias Eul[1], Florian Haag[1], Benjamin Frisch[1], Philip Thielen[1], Martin Piecuch[1], Mirko Cinchetti[2], Martin Aeschlimann[1], and Benjamin Stadtmüller[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Experimentelle Physik VI, Technische Universität Dortmund, 44221 Dortmund, Germany

Electron dynamics in solid state systems and at interfaces play a crucial role for the performance of nanoscale spintronic devices. Therefore, it is essential to investigate the electron dynamics in the materials used for such devices.

The inelastic lifetimes of electronic states can be directly obtained with time resolved two-photon photoemission, using a cross-polarized pump-probe setup. Combining this technique with momentum spectroscopy in a ToF-PEEM operated in K-space mode, we are able to observe the energy dependent electron dynamics for each point in the accessible momentum space. This allows us to analyze cross-correlation traces for different intermediate state energies and different positions in the k_x/k_y-plane. As first model systems, we focused on bulk states of simple noble metal surfaces using different angles of incide of laser light. Based on the observed behavior, we aim to tune the electron lifetime of the metal surface by adsorption of organic molecules

MA 31.4 Tue 18:30 P2-EG

Ab initio approach to the ion stopping power at the plasma-solid interface — Karsten Balzer, •Niclas Schlünzen, Jan-Philip Joost, Lasse Wulff, and Michael Bonitz — CAU Kiel, Germany

The energy loss of ions in solids is of key relevance for many applications of plasmas, ranging from plasma technology to fusion. Standard approaches are based on density functional theory or SRIM simulations, however, the applicability range and accuracy of these results are difficult to assess, in particular, for low energies. Here, we present an independent approach that is based on ab initio nonequilibrium Green functions theory, e.g. [1,2] that allows to incorporate electronic correlations effects of the solid. As first application of this method to low-temperature plasmas, we concentrate on proton and alpha-particle stopping in a graphene layer and similar finite honeycomb lattice systems. In addition to the stopping power we present time-dependent results for the local electron density, the spectral function and the photoemission spectrum [3] that is accessible in optical, UV or x-ray diagnostics [4].

[1] M. Bonitz, *Quantum Kinetic Theory, 2nd edition* (Springer, 2016)
[2] K. Balzer and M. Bonitz, Lect. Notes Phys. **867** (2013)
[3] M. Eckstein and M. Kollar, Phys. Rev. B **78**, 245113 (2008)
[4] K. Balzer, N. Schlünzen, and M. Bonitz, Phys. Rev. B, accepted for publication, arXiv:1602.06928 (2016)

MA 31.5 Tue 18:30 P2-EG

Ultrafast transition to a hidden state in $1T$-TaS$_{2-x}$Se$_x$ single crystals — •Ljupka Stojchevska[1,2], Ebru Ekici[3], Kira Kolpatzeck[3], Christian A. Bobisch[3], Dragan Mihailovic[1], and Uwe Bovensiepen[2] — [1]Complex Matter Department, Jozef Stefan Institute, Ljubljana, Slovenia — [2]Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany — [3]Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Duisburg, German

We report on femtosecond pump-probe spectroscopy study on the relaxation dynamics in $1T$-TaS$_{2-x}$Se$_x$ single crystals with 6%, 7.5%, 17% and 19% selenium doping. We observe a transition to a new hidden state [1] (H-state) which is inaccessible under normal equilibrium conditions and can only be reached after a quench with a single femtosecond laser pulse at 1.6-4.8 mJ/cm^2 fluence. Similarly as in [1], a notable change in the coherent phonon spectra plays the role of the fingerprint of the successful switching to a new state via optical path. The major output is observation of the significantly higher temperature stability of the H-state ($\sim$ 104 K) in comparison with the parent $1T$-TaS$_2$ material ($\sim$ 70 K). In addition, intense experimental efforts are currently undergoing in order to microscopically characterize H-state by means of scanning tunneling microscopy (STM) and to investigate the electronic structure with femtosecond time- and angle-resolved photoemission spectroscopy (trARPES). [1] Stojchevska, L. et al., Science, 344, 177 (2014).

MA 31.6 Tue 18:30 P2-EG

Characterization of an ultrafast MHz electron point source — •Jannik Malter, Melanie Müller, Faruk Krecinic, and Ralph Ernstorfer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

Ultrafast electron point sources allow for electron microscopy and diffraction [1] as well as scanning probe techniques [2] with very high spatial and temporal resolution. The laser repetition rate is a crucial parameter as it directly influences statistics of the measurement, and taking the required laser pulse energy into account determines the thermal stress on the tip. We discuss photoemission from a metal tip using an optical parametric amplified laser in the low-MHz regime. Photoemission is either triggered by direct illumination of the apex, or by excitation and nanofocusing of surface plasmon polaritons [3]. Due to the better thermal response of the tip, the latter approach could possibly lead to femtosecond electron holography and contribute to laser-triggered ultrafast STMs.

[1] Müller et al. Femtosecond electrons probing currents and atomic structure in nanomaterials. Nature Comm. 5, 2014
[2] Cocker et al. Tracking the ultrafast motion of a single molecule by femtosecond orbital imaging. Nature 539, 2016
[3] Müller et al. Nanofocused Plasmon-Driven Sub-10 fs Electron Point Source. ACS Photonics 3 (4), 2016

MA 31.7 Tue 18:30 P2-EG

Mahan cone formation and time-resolved two-photon photoemission of the adsorbate system Tin-Phthalocyanine on Ag(111) — •Stephan Jauernik, Petra Hein, Max Gurgel, Julian Falke, and Michael Bauer — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

Recently, the adsorption of tin-phthalocyanine (SnPc) on Ag(111) has attracted considerable interest due to peculiarities in the adsorbate-substrate interaction and switching capabilities reported for the adsorbed SnPc [1]. Using Low Energy Electron Diffraction (LEED) and Photoemission/Two-Photon Photoemission (PES/2PPE) we address in this work the correlation of structural and electronic properties of this model-type system in the incommensurate adsorption phase which forms in the coverage regime between 0.90 ML and 1.0 ML. 1PPE data of 1ML SnPc on Ag(111) reveal the formation of Mahan cones [2,3] which we associate with a direct optical transition within the Ag sp-band modified by diffraction in the presence of the 2D adsorbate superstructure. Using time-resolved bichromatic 2PPE we focus on the electronic structure of the adsorbate layer and the characteristic relaxation dynamics of molecular resonances.

[1] C. Stadler et al., Nature Physics 5, 153 (2009)
[2] G. D. Mahan, Phys. Rev. B 2, 4334 (1970)
[3] Winkelmann et al., New Journal of Physics, Volume 14 (2012)

MA 32: Focus Session: Magnetic Correlations in Mesoscopic Spin Structures

Organized by Naëmi Leo (Paul Scherrer Institut Villingen) and Laura Heyderman (ETH Zürich)

Mesoscopic magnetic systems offer a unique way to create and study novel functionalities, from controlling the way in which single nanomagnets interact to observing emergent thermal behaviour. This focus session aims to bring together scientists investigating coupling phenomena, field-driven behaviour, and magnetic correlations in mesoscopic magnetic systems fabricated by nanolithography or self-assembly.

Time: Wednesday 9:30–12:15 Location: HSZ 01

Invited Talk MA 32.1 Wed 9:30 HSZ 01

Collective modes in magnonic vortex crystals — •Guido Meier — Max-Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149 22761 Hamburg, Germany

Collective modes in stacked disks containing magnetic vortices are investigated by ferromagnetic resonance spectroscopy and scanning transmission X-ray microscopy. In laterally coupled arrangements it has been shown recently that memory-like writing processes are possible based on the excitation of the gyrotropic mode [1]. We make use of the vertical dimension in tailored vortex stacks that drastically increases possible storage densities. The dynamics of all binary states emergent in a stack of vortices are directly observed [2]. The size of the arrangements is increased step by step to identify the different contributions to the interaction between the vortices. These contributions are the key requirement to understand complex dynamics of three dimensional vortex crystals. Both vertical and horizontal coupling determine the collective modes. In-plane dipoles strongly influence the interaction between the disks in the stacks and lead to polarity-dependent resonance frequencies [3]. Weaker contributions discern arrangements with different polarities and circularities that result from the lateral coupling of the stacks and the interaction of the core regions inside a stack. [1] M. Hänze, C. F. Adolff, M. Weigand, and G. Meier, Phys. Rev. B 91, 104428 (2015) [2] M. Hänze, C. F. Adolff, S. Velten, M. Weigand, and G. Meier, Phys. Rev. B 93, 054411 (2016) [3] M. Hänze, C.F. Adolff, B. Schulte, J. Möller, M. Weigand, and G. Meier, Sci. Rep. 6, 22402 (2016)

Invited Talk MA 32.2 Wed 10:00 HSZ 01
Stability of interfacial Skyrmions, Solitons and Bound Monopoles: How to store Energy in topological magnetic Quasiparticles. — •Elena Vedmedenko — University of Hamburg, Germany

One of the most exciting recent developments in nanomagnetism concerns topologically non-trivial magnetic configurations acting as quasiparticles. Among these quasiparticle excitations are three- or two-dimensional magnetic skyrmions, one-dimensional topological helices and zero-dimensional monopoles, which can also be bound by one-dimensional Dirac strings. Once created, magnetic quasiparticles can only be erased with effort from a surface. This makes them valuable for the application in future data storage devices but also poses fundamental questions on the microscopic reasons for the topological stability. Here, analytical and numerical analyses are used to study the dynamics and life-times of skyrmions, topological helices and bound monopoles in continuous and structured magnetic thin films. Additional attention is paid to the interaction between magnetic quasiparticles. It is shown that the main reason for the enhanced stability is a dynamical behavior of an energy barrier rather than its height. Interactions between quasiparticles, e.g. in spin-ices, are defined by the characteristic tension-to-mass ratio proportional to the fine structure constant and lattice parameters. On the basis of this analysis, a theoretical concept of the energy storage at the nanoscale is proposed and compared with recent experiments.

Invited Talk MA 32.3 Wed 10:30 HSZ 01
Exploring the statistical physics of frustrated spin systems with artificial spin ice — •Ian Gilbert[1], Yuyang Lao[2], Sheng Zhang[3], Gia-Wei Chern[4], Robert Ilic[1], Daniel Pierce[1], Cristiano Nisoli[5], John Unguris[1], and Peter Schiffer[2] — [1]Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD USA — [2]Department of Physics and Frederick Seitz Materials Research Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL USA — [3]Materials Science Division, Argonne National Laboratory, Argonne, IL USA — [4]Physics Department, University of Viriginia, Charlottesville, VA USA — [5]Theoretical Division and Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM USA

Arrays of nanomagnets known as artificial spin ice provide unique and valuable insight into the statistical physics of frustrated magnetism because the lattice geometry can be arbitrarily tuned and the exact configuration of the constituent magnetic moments can be directly imaged. Here I describe several recent studies of correlations and emergent phenomena in artificial spin ice with several new lattice geometries. First, the shakti lattice possesses an extensively-degenerate ground state analogous to natural spin ice materials as well as magnetic charge screening. Second, the tetris lattice exhibits reduced dimensionality and frustration-dependent thermal fluctuations. Finally, I will discuss ongoing efforts to investigate artificial spin ice with randomness built in to the island locations.

15 min. break

Invited Talk MA 32.4 Wed 11:15 HSZ 01
Skyrmions in [Pt/Co/Ir] multilayers at room temperature — •Katharina Zeissler[1], Simone Finizio[2], Jörg Raabe[2], Michal Mruczkiewicz[3], Philippa Shepley[1], Thomas Moore[1], Gavin Burnell[1], and Christopher Marrows[1] — [1]School of Physics and Astronomy, Leeds University, E.C. Stoner Building, Leeds, UK, LS2 9JT — [2]Paul Scherrer Institute, 5232 Villigen, Switzerland — [3]Institute of Electrical Engineering, Slovak Academy of Sciences, Dubravska Cesta 9, SK-841-04 Bratislava, Slovakia

Magnetic quasiparticles such as skyrmions are important objects in the quest for novel magnetic information storage. They have been observed in bulk materials as well as in multilayer systems. The latter has great scope for applications due to skyrmion stability at room temperature. The nucleation, manipulation and detection of skyrmions are active research areas. The focus of this talk will be skyrmion stabilisation and detection in [Pt/Co/Ir] multilayer nanodiscs and their manipulation via external stimuli such as external magnetic fields and current pulses. Chiral spin textures, including skyrmion bubbles, were stabilised in nanodiscs and imaged using scanning X-ray microscopy and their electrical response was measured in situ. This setup allowed for a direct comparison between the chiral magnetic state and its electrical transport signature. The influence of pinning due to stack imperfections was found to be of importance for skyrmion stabilisation.

Invited Talk MA 32.5 Wed 11:45 HSZ 01
Artificial magnets as model systems : from the fragmentation of magnetization to the seminal square ice model — •Benjamin Canals, Yann Perrin, Ioan Chioar, and Nicolas Rougemaille — Institut NEEL, Grenoble, France

Complex architectures of nanostructures are routinely elaborated using bottom-up or nanofabrication processes, allowing scientists to engineer frustrated arrays that do not exist in nature. These systems have been the subject of intense research in the last few years and have allowed the investigation of fascinating phenomena, such as the observation of pseudo-excitations involving classical analogues of magnetic charges. This talk aims at providing two examples of two-dimensional artificial magnets which allow to probe the low energy manifolds of two exotic Ising systems.

The first one is related to the seminal square ice model and shows that it is possible to perform a scan through the 6-vertex model phase diagram with an appropriately designed artificial magnet [1]. The second one refers to a recent proposal, the fragmentation of magnetization [2], in an Ising kagome model, which corresponds to the effective splitting of the local degree of freedom into two channels independent channels [3].

[1] Y. Perrin, B. Canals, N. Rougemaille, Nature 540, 410-413 (2016). [2] M. E. Brooks-Bartlett et al., Phys. Rev. X, 4, 011007 (2014). [3] B. Canals et al., Nat. Comm. 7, 11446 (2016).

MA 33: Transport: Quantum Coherence and Quantum Information Systems - Experiment (jointly with MA, HL)

Time: Wednesday 9:30–13:00 Location: HSZ 03

MA 33.1 Wed 9:30 HSZ 03

Adiabatic two-qubit state preparation in a superconducting qubit system — •Marc Ganzhorn[1], Daniel Egger[1], Andreas Fuhrer[1], Nikolaj Moll[1], Peter Mueller[1], Marco Roth[2], Sebastian Schmidt[3], and Stefan Filipp[1] — [1]IBM Schweiz, Rueschlikon, Schweiz — [2]Department fuer Physik, RWTH Aachen, Deutschland — [3]Institut fuer Theoretische Physik, ETH Zuerich, Schweiz

The adiabatic transport of a quantum system from an initial eigenstate to its final state while remaining in the instantaneous eigenstate of the driving Hamiltonian can be used for robust state preparation. With control over both qubit frequencies and qubit-qubit couplings this method can be used to drive the system from initially trivial eigenstates of the uncoupled qubits to complex entangled multi-qubit states. In the context of quantum simulation, the final state may encode a non-trivial ground-states of a complex molecule, or the solution to an optimization problem in the context of adiabatic quantum computing. Here we present experimental results on a system comprising fixed-frequency superconducting transmon qubits and a tunable coupler to adjust the qubit-qubit coupling via parametric frequency modulation. We realize different types of interaction terms by adjusting the frequency of the modulation. A slow variation of drive amplitude and phase leads to an adiabatic steering of the system to its final state showing entanglement between the qubits.

MA 33.2 Wed 9:45 HSZ 03

Second-order decoherence mechanisms of a transmon qubit probed with thermal microwave states — •Frank Deppe[1,2,3], Jan Goetz[1], Peter Eder[1,2,3], Michael Fischer[1,2,3], Stefan Pogorzalek[1,2,3], Edwar Xie[1,2,3], Kirill G. Fedorov[1,2], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

Using thermal microwaves as a probe, we identify three second-order decoherence mechanisms of a superconducting transmon qubit. First, we quantify the efficiency of a resonator filter in the dispersive Jaynes-Cummings regime and find evidence for parasitic loss channels. Second, we probe second-order noise in the low-frequency regime and demonstrate the expected T^3 temperature dependence of the qubit dephasing rate. Finally, we show that qubit parameter fluctuations due to two-level states are enhanced under the influence of thermal microwave states. In particular, we present experimental evidence for a model based on noninteracting two-level states.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria, and the IMPRS ‘Quantum Science and Technology’.

MA 33.3 Wed 10:00 HSZ 03

Probing broadband engineered and residual environments with a transmon qubit — •P. Eder[1,2,3], F. Deppe[1,2,3], T. Le Anh[1,2], J. Goetz[1,2], M. Fischer[1,2,3], E. Xie[1,2,3], A. Marx[1], and R. Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

Microwave beam splitters and transmon qubits are important components in circuit quantum electrodynamics (QED). Arranging two beam splitters in the form of an interferometer, we engineer a non-trivial broadband on-chip environment. We place the transmon qubit as a sensitive probe inside this environment and perform resonance fluorescence measurements. When comparing the experimental results with predictions from the spin-boson model, we find good agreement. Small deviations between experiment and theory indicate the presence of spurious electromagnetic modes. In general, our results demonstrate how to design and scale up complex circuits for experiments on propagating quantum microwaves.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria and the IMPRS ‘Quantum Science and Technology’.

MA 33.4 Wed 10:15 HSZ 03

Chains of nonlinear and tunable superconducting resonators — •M. Fischer[1,2,3], P. Eder[1,2,3], J. Goetz[1,2], S. Pogorzalek[1,2], E. Xie[1,2,3], K. Fedorov[1,2], F. Deppe[1,2,3], A. Marx[1], and R. Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

We present the theoretical analysis and experimental study of a quantum simulation system of the Bose-Hubbard Hamiltonian in the driven dissipative regime in the realm of circuit QED. The system consists of series-connected, capacitively coupled superconducting resonators which are both nonlinear and tunable. The nonlinearity is achieved by galvanically coupled SQUIDs. They are placed in the current antinode of each resonator and can be tuned by external coils and on-chip antennas.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria and the IMPRS ‘Quantum Science and Technology’.

MA 33.5 Wed 10:30 HSZ 03

Towards a scalable 3D quantum memory — •Edwar Xie[1,2,3], Frank Deppe[1,2,3], Daniel Repp[2], Peter Eder[1,2,3], Michael Fischer[1,2,3], Jan Goetz[1,2,3], Kirill G. Fedorov[1], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

For superconducting qubits dispersively coupled to 3D cavity resonators both T_1-and T_2-times in excess of $100\,\mu$s have been achieved. However, the 3D cavities are bulky in comparison with their (slightly less coherent) 2D counterparts. A more scalable device can be built by exploiting the multi-mode structure of the 3D cavity. Here, we present an experimental study on such a device: a transmon qubit capacitively coupled to two distinct modes of a single 3D cavity. We engineer the fundamental and the first harmonic mode of a single cavity in such a way, that the former one couples well to the external feedline, whereas the latter does not. The qubit is dispersively coupled to both modes with a rate $g/2\pi \simeq 60\,$MHz. Using a second-order coupling protocol, we observe an enhancement in qubit lifetime by a factor of 3 compared to the pure qubit lifetime and find that this value is not limited by fundamental constraints.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria and the IMPRS ‘Quantum Science and Technology’.

MA 33.6 Wed 10:45 HSZ 03

Finite-time correlations of balanced two-mode squeezed microwave states — •Kirill Fedorov[1,2], Stefan Pogorzalek[1,2], Patrick Yard[1,2], Peter Eder[1,2,3], Michael Fischer[1,2,3], Jan Goetz[1,2], Edwar Xie[1,2,3], Achim Marx[1], Frank Deppe[1,2,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

Generation of balanced two-mode squeezed states is a key task in quantum communication and illumination with continuous variables, as it enables distribution of quantum entanglement between distant parties. For this reason, the investigation of such states is of high interest in the field of propagating quantum microwaves. In our work, we perform tomography of balanced two-mode squeezed microwave states which are created by the means of two flux-driven Josephson parametric amplifiers generating orthogonally squeezed states at the inputs of a $50:50$ microwave beam splitter. We study finite-time correlations in order to measure a characteristic time of entanglement decay in quantum channels. Our studies show that quantum communication and illumination protocols with continuous-variable propagating microwaves are experimentally feasible.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria, and the IMPRS ‘Quantum Science and Technology’.

MA 33.7 Wed 11:00 HSZ 03

Impact of noise on entanglement of two-mode squeezed microwave states — •S. Pogorzalek[1,2], K. G. Fedorov[1,2], P. Yard[1,2], P. Eder[1,2,3], M. Fischer[1,2,3], J. Goetz[1,2], E. Xie[1,2,3], A. Marx[1], F. Deppe[1,2,3], and R. Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

Propagating quantum signals in the form of microwave two-mode squeezed states (TMSSs) can be generated by utilizing Josephson parametric amplifiers (JPAs). In our experiments, we employ two flux-driven JPAs at the inputs of an entangling hybrid ring in order to generate TMSSs between the hybrid ring outputs. This allows us to generate quantum entangled propagating microwave signals suitable for quantum communication and sensing applications such as quantum teleportation and quantum radar. However, the performance of these schemes may drastically depend on the amount of environmental noise in the communication channels. We study this dependence experimentally by controlling the amount of excess noise in different parts of the setup. Finally, we investigate the robustness of entanglement to thermal and shot noise via a negativity criterion and determine fundamental negativity-versus-noise limits.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria, and the IMPRS ‘Quantum Science and Technology’.

15 min. break.

MA 33.8 Wed 11:30 HSZ 03

Tailoring coupling in artificial superconducting quasi-spins — •Alexander Stehli, Jochen Braumüller, Andre Schneider, Hannes Rotzinger, Martin Weides, and Alexey V. Ustinov — Physikalisches Institut, Karlsruhe Institute of Technology

Due to their intrinsic coherence and easy accessibility, superconducting circuits are a promising platform for building a universal quantum computer. Such devices could solve virtually any quantum problem, however many qubits are required in order to achieve quantum supremacy. A more direct, alternative approach is provided by analog quantum simulation. By synthesizing the Hamiltonian of a quantum system with a simulator, the eigenstates and time evolution are investigated without accessing the original system.

In this work, we explore the properties of two coupled concentric transmon qubits. We show strong XX-interaction with a coupling strength of 12 MHz between the qubits. This value is extracted from spectroscopy measurements and confirmed by vacuum Rabi oscillations, in good agreement with electrodynamic calculations.

These results pave way towards future experiments on the quantum dynamics of larger systems with multiple artificial quasi-spins. The concentric transmon is expected also to feature ZZ-coupling, when biased at frequencies away from the flux sweet spot. Depending on the accessible parameter range, the simulation of the Fermi-Hubbard model is offered by a theoretical model. In this contribution, we will show our experimental and numerical data and provide an outlook on performing quantum simulation with concentric transmon qubits.

MA 33.9 Wed 11:45 HSZ 03

Probing the strong coupling regime between microwave resonators and YPc_2 molecule ensembles — •Yannick Schön[1], Eufemio Pineda[2], Hannes Rotzinger[1], Marco Pfirrmann[1], Andre Schneider[1], Julius Krause[1], Sebastian T. Skacel[1], Mario Ruben[2], Alexey V. Ustinov[1], and Martin Weides[1,3] — [1]Karlsruhe Institute of Technology, Institute of Physics — [2]Karlsruhe Institute of Technology, Institute of Nanotechnology — [3]Johannes Gutenberg-University Mainz, Institute of Physics

We investigate magnetic molecule ensembles with microwave signals in the low GHz range. This offers a measurement and manipulation framework, which can reliably be integrated into hybrid quantum systems, and facilitates joint applications of magnetic molecules in the rapidly growing field of quantum information processing.

The studied material family of lanthanide or metal Phtalocyanine 2 compounds exhibits a wide range of splittings between their electronic states, as well as molecular anisotropy, depending on the central ion. Our setup facilitates probing dynamics of different molecules with a 3d cavity in dependence of temperature, power or magnetic field.

In particular, the strong coupling of Yttrium Pc2 (YPc_2) to microwave resonators has been investigated between 25 mK and 20 K, and compared to simulation based on input-output theory. The extracted parameters contain information about the sample transitions, their linewidth, and coupling strength down to the quantum regime. Furthermore, on-chip integration of molecule ensembles with superconducting niobium 2d resonators is demonstrated.

MA 33.10 Wed 12:00 HSZ 03

A pulsed electron paramagnetic resonance spectrometer operating at millikelvin temperatures — •Stefan Weichselbaumer[1,2], Christoph W. Zollitsch[1,2], Kai Müller[1,2], Petio Natzkin[1,2], Sebastian T. B. Goennenwein[1,2,3], Martin S. Brandt[2,4], Rudolf Gross[1,2,5], and Hans Huebl[1,2,5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany — [4]Walter Schottky Institut, Technische Universität München, Garching, Germany — [5]Nanosystems Initiative Munich, Munich, Germany

Electron paramagnetic resonance (EPR) is an ubiquitous spectroscopy tool which is employed in many areas of research. One critical aspect for any application is the sensitivity of the spectrometer which scales with the degree of spin polarization in the sample. In the paramagnetic case, this spin polarization is determined by the ratio of magnetic field and temperature, B/T. Here, we report on the implementation of a pulsed EPR spectrometer using superconducting microwave resonators, operating at millikelvin temperatures. We investigate a spin ensemble of phosphorus donors embedded in an isotopically purified nuclear spin free ^{28}Si environment, which exhibits a thermal spin polarization close to unity at 50 mK. Our high sensitivity allows for single-shot measurements with an exceptional signal-to-noise ratio SNR $\gg 1$ for approximately 10^8 spins.

This work was supported by the DFG via SPP 1601 (HU1861/2-1).

MA 33.11 Wed 12:15 HSZ 03

Engineering the parity of light-matter interaction in superconducting circuits — •J. Goetz[1], C. Besson[1,2], P. Eder[1,2,3], M. Fischer[1,2,3], S. Pogorzalek[1,2,3], E. Xie[1,2,3], K.G. Fedorov[1,2], F. Deppe[1,2,3], A. Marx[1], and R. Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

In physics, parity describes the symmetry properties of quantum states and operators under spatial inversion. It has manifold applications in the standard model, quantum information and field theory. We present a novel technique for the in-situ control of the interaction operator parity in superconducting quantum circuits. Using a tunable-gap gradiometric flux qubit, which exhibits both a dipole and a quadrupole moment, we can precisely engineer the interaction parity with spatially shaped microwave fields. Our highly symmetric sample architecture enables a complete parity inversion and the observation of transparency induced by longitudinal coupling. In a second step, we couple the qubit to a resonator and, in this way, activate quadrupolar transitions similar to those in multi-electron atoms. Our work paves the way towards parity based quantum simulation and physical applications based on longitudinal light-matter interaction.

The authors acknowledge support from DFG through FE 1564/1-1, the doctorate program ExQM of the Elite Network of Bavaria, and the IMPRS ‘Quantum Science and Technology’.

MA 33.12 Wed 12:30 HSZ 03

Near quantum-limited amplification and conversion based on a voltage-biased Josephson junction — •Salha Jebari[1,2], Florian Blanchet[1,2], Romain Albert[1,2], Dibyendu Hazra[1,2], and Max Hofheinz[1,2] — [1]CEA, Grenoble,France — [2]Université Grenoble Alpes, Grenoble, France

Recent experiments with superconducting circuits consisting of a DC voltage-biased Josephson junction in series with a resonator have shown that a tunneling Cooper pair can emit one or several photons with a total energy of 2e times the applied voltage. We present microwave reflection measurements on the device in , indicating that amplification is possible with a simple DC voltage-biased Josephson junction. We also show that this amplification adds noise close to the limit set by quantum mechanics for phase preserving amplifiers. For low Josephson energy, transmission and noise emission can be explained within the framework of P(E) theory of inelastic Cooper

pair tunneling and are related to the fluctuation dissipation theorem (FDT). We also experimentally demonstrate, by controlling the applied DC voltage, that our device can act as both an amplifier and a frequency converter. Combined with a theoretical model, our results indicate that voltage-biased Josephson junctions might be useful for amplification near the quantum limit, being powered by simple DC voltage and providing a different trade-off between gain, bandwidth and dynamic range, which could be advantageous in some situations.

MA 33.13 Wed 12:45 HSZ 03

Josephson-photonics devices as source of non-classical microwave radiation — •Björn Kubala[1], Joachim Ankerhold[1], Chloe Rolland[2], Marc P. Westig[2], Iouri Moukharski[2], Daniel Esteve[2], and Fabien Portier[2] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany — [2]CEA Saclay, Gif-sur-Yvette, France

Sources of non-classical photons have important applications in quantum communication and sensing technologies. With non-classical microwave sources these are extended to circuit-QED setups extensively used for various quantum information tasks.

Here, we report recent experimental result, demonstrating that a dc-biased Josephson junction embedded in a carefully engineered electromagnetic environment constitutes a new source of bright non-classical radiation. We will explain, why in such a “Josephson-photonics” device with a single mode of large impedance strongly anti-bunched photons are produced, opening the path to a single-photon source in the microwave range. A Cooper-pair crossing a junction, which is coupled to two resonators, under the proper dc-bias emits a pair of photons into the two resonators and thus produces correlated light with strongly reduced noise [1]. Measurements of this noise reduction factor demonstrate the non-classical nature of the light source.

[1] A. D. Armour, B. Kubala, and J. Ankerhold, Phys. Rev. B **91**, 184508 (2015)

MA 34: Spin Dynamics and Transport: Magnonics

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

MA 34.1 Wed 9:30 HSZ 04

Direct Microscopic Observation of Spin Wave Focussing in a Fresnel Lens — •Joachim Gräfe[1], Martin Decker[2], Kahraman Keskinbora[1], Matthias Noske[1], Przemysław Gawronski[3], Hermann Stoll[1], Christian H. Back[2], Gisela Schütz[1], and Eberhard J. Goering[1] — [1]MPI für Intelligente Systeme, Stuttgart — [2]Universität Regensburg, Regensburg — [3]AGH University of Science and Technology, Krakau, Polen

Manipulation of spin waves has recently gained significant scientific interest. Structuring of a spin system on the length scale of the exchange and dipole interactions allows the engineering of spin wave properties. By scanning x-ray microscopy it is possible to image spin wave propagation with spatial and time resolution of about 25 nm and 45 ps with high magnetic contrast based on the XMCD effect. Using this technique we explore the focusing properties of an interference based Fresnel lens for spin waves. We observed a focal spot confined to less than 800 nm at a distance of more than 5 μm from the zone plate. The intensity is increased by more than 20% above the emission intensity. Thus, the lens is effectively overcompensating the damping during spin wave propagation. Furthermore, the focal spot can be moved easily by changing the applied magnetic bias field in the mT range. Thus, this type of spin wave lens can provide a flexible intense spin wave spot and an effective magnon source for different magnonic or spintronic devices.

MA 34.2 Wed 9:45 HSZ 04

Writing magnonic waveguides in FeAl with an nano-sized ion beam — •Julia Osten, Tobias Hula, Kai Wagner, Xiaomo Xu, Gregor Hlawacek, Rantej Bali, Kay Potzger, and Helmut Schultheiss — Institute of Ion Beam Physics and Material Research , HZDR, Dresden, Germany

Spin waves, the eigen-excitations of ferromagnets, are promising candidates for spin transport in lateral devices. $Fe_{60}Al_{40}$ films in the B2 phase are paramagnetic. Starting from a FeAl film in the paramagnetic phase the incident ions randomize the site occupancies and, thereby, transform it into the chemically disordered, ferromagnetic A2 phase.
The aim is to investigate spin wave propagation in this ferromagnetic material in free standing structures as well as in ferromagnetic structures embedded within a paramagnetic matrix. Using Helium-Ion microscopy we create spatially well defined ferromagnetic FeAl conduits for spin waves with resolution down to nm range. Two different ferromagnetic stripes were implanted in a microstructured paramagnetic FeAl. A freestanding 2 μm width stripe. And a stripe of the same width which was embedded in a wider paramagnetic FeAl stripe. For the excitation of spin waves we processed a microwave antenna on top of these stripes. To detect spin waves we employed Brillouin light scattering microscopy. We show that the spin wave spectra are influenced by the surrounding paramagnetic material due to a different internal field distribution. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

MA 34.3 Wed 10:00 HSZ 04

Spin-Wave Mode Conversion via Optically Induced Landscapes of the Saturation Magnetization — •Marc Vogel[1], Rick Assmann[1], Andrii V. Chumak[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Fraunhofer-Institute for Physical Measurement Techniques IPM, Fraunhofer-Platz 1, 67663 Kaiserslautern, Germany

Magnons - eigen excitations of the electrons’ spin system - are seen as a potential candidate for future data processing. For this, in-plane magnetized samples are the first choice because they do not require a large biasing field. However, due to a strong spin-wave anisotropy the backward volume magnetostatic spin waves (BVMSW) propagating along the biasing field and the magnetostatic surface spin waves (MSSW), propagating perpendicularly, exist in different frequency ranges.

Here, we use our recently reported technique of laser modified magnetic media [Nature Physics 11, 487 (2015)] to realize a highly efficient method to convert BVMSW to MSSW. Computer generated holograms are used to heat up the sample locally (due to the optical absorption). A temperature gradient evolves inside the waveguide resulting in a shift of the dispersion relations to lower frequencies. Thus, MSSW- and BVMSW-bands are formed. Both intersect with each other leading to the BVMSW-MSSW-mode conversion.

Financial support by DFG collaborative research center SFB/TTR 173 "Spin+X" (project B04) is gratefully acknowledged.

MA 34.4 Wed 10:15 HSZ 04

Snell’s law for spin waves in a temperature gradient — •Michael Vogel, Johannes Stigloher, Martin Decker, and Christian H. Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany

Snell’s law [J. W. Shirley. Am. J. Phys. 19, 507 (1951)] describes the relationship between incidencent and refracted parts of a wave in media with different group velocities by following Fermat’s principle of least time. It is mainly prominent in optics, but due to only being based upon a translational symmetry argument applicable to many phenomena such as spin waves [J. Stigloher et al. PRL. 117, 037204 (2016)]. The dispersion relation for spin waves depends on the saturation magnetization which depends itself on temperature [7]. Here the transition of spin wave through a locally heated Permalloy film is studied by time resolved MOKE measurements. We show the possibility of changing the direction of spin waves by local manipulation of the temperature landscape.

MA 34.5 Wed 10:30 HSZ 04

Broadband spin-wave spectroscopy (BSWS) and micro-focused Brillouin Light Scattering (μBLS) on a nanostructured ferrimagnetic thin film — •Stefan Mändl[1], Ioannis Stasinopoulos[1], and Dirk Grundler[2] — [1]Physik Department E10, TU München, Garching, Germany — [2]Institut des Matériaux, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Magnonics is a growing research field where one aims at controlling spin waves on the nanoscale. Microwave-to-magnon transducers are in particular important for coupling magnonic devices to conventional microwave circuits. In 20 nm thick yttrium iron garnet (YIG) it was found that the reciprocal-lattice vector provided by a periodic array of Py nanodisks added to the wave vector of a Damon-Eshbach mode [1]. We study the effect in thick YIG of 200 nm by broadband spin-wave spectroscopy and micro-focused Brillouin Light Scattering. Two-dimensional lattices of different geometries are prepared with Electron Beam Lithography and Evaporation of Py. We find varying spin-wave decay lengths for different geometries and resolve spin-waves with wavelength down to 100 nm. The work is supported by the DFG via GR1640/5 in SPP 1538 and NIM.

[1] H. Yu et al., Nat. Commun. 7, 11255 (2016)

MA 34.6 Wed 10:45 HSZ 04

Frequency modulation of backward volume spin wave by electric current — •Nana Nishida[1], Seo-Won Lee[2], Seung-Jae Lee[3], Kyung-Jin Lee[2,3], Helmut Schultheiss[1], and Koji Sekiguchi[4,5] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Department of Materials Science and Engineering, Korea University, Seoul, Korea — [3]KU-KIST Graduated School of Converging Science and Technology, Korea University, Seoul, Korea — [4]Department of Physics, Keio University, Yokohama, Japan — [5]JST-PRESTO, Tokyo, Japan

In the field of magnonics, spin waves are envisioned as a new candidate for information transport and processing. Since spin waves propagate without any charge displacement and are free from Joule heating, they offer significant reduction of energy consumption in devices. The spin transfer torque (STT) effect originating from conduction electrons is a powerful method for modulating spin waves. Here, we investigated the current induced Doppler shift of backward volume spin waves.

We fabricated a NiFe stripe with a width of 2 μm, which was magnetized in backward volume configuration. The antennas fabricated on top of the NiFe stripe were connected to a vector network analyzer for measuring the spin-wave spectra. We applied a dc current to the NiFe stripe. For a current density of 5×10^{10} A/m^2 the spin-wave frequencies shifted +170 MHz compared to the spin-wave spectra without dc current. This frequency shift is 60 times larger than previous works reported for forward volume spin waves. Hence, we demonstrated giant frequency modulation of backward volume spin waves by a dc current.

15 min. break

MA 34.7 Wed 11:15 HSZ 04

Curvature-Induced Asymmetry of Spin-Wave Dispersion — Jorge A. Otálora[1], Ming Yan[2], Helmut Schultheiss[3], Jürgen Lindner[3], Jürgen Fassbender[3], Riccardo Hertel[4], and •Attila Kákay[3] — [1]Universidad Técnica Federico Santa María, Avenida España 1680, Casilla 110-V, Valparaíso, Chile — [2]Shanghai University, 99 Shangda Road, Shanghai 200444, China — [3]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [4]IPCMS, UMR 7504, CNRS, and Université de Strasbourg, 23 rue du Loess, F-67034 Strasbourg, France

We show using micromagnetic simulations and analytical calculations that spin-wave propagation in ferromagnetic nanotubes is fundamentally different than in flat thin films. The dispersion relation is asymmetric regarding the sign of the wave vector. This is a purely curvature-induced effect and its fundamental origin is identified to be the classical dipole-dipole interaction. In certain cases the Damon-Eshbach modes in nanotubes behave as the volume-charge-free backward volume modes in flat thin films. Such non-reciprocal spin-wave propagation [1] is known for flat thin films with Dzyalonshiinsky-Moriya interaction (DMI), an antisymmetric exchange due to spin-orbit coupling. The analytical expression of the dispersion relation has the same mathematical form as in flat thin films with DMI. The influence of curvature on spin waves is thus equivalent to an effective dipole-induced Dzyalonshiinsky-Moriya interaction [2]. [1] K. Zakeri, et. al., Phys. Rev. Lett. **104**, 137203 (2010). [2] J.A. Otálora, et. al., Phys. Rev. Lett. **117**, 227203 (2016).

MA 34.8 Wed 11:30 HSZ 04

Anderson Localization in antiferromagnets: comparing length and time scales to ferromagnets — •Martin Evers, Coralie Schneider, Cord A. Müller, and Ulrich Nowak — University of Konstanz, D-78457 Konstanz

As Anderson showed in 1958, in case of phase coherent transport disorder can lead to completely suppressed transport, a phenomenon known as Anderson localization [1]. For the case of spin waves this will lead to a limited propagation, even without any dissipative damping mechanism [2,3].

In the field of spin transport there is a growing interest in antiferromagnets and other materials with multiple magnetic sublattices. We investigate numerically magnonic transport with respect to Anderson localization in one and two dimensional antiferromagnets. The relevant time and length scales of weak and strong localization are compared to ferromagnets. We find clear differences, especially a much shorter localization length in antiferromagnets.

[1] P. W. Anderson, Phys. Rev. **109**, 1492 (1958)
[2] U. Ritzmann et al., Phys. Rev. B **89**, 024409 (2014)
[3] M. Evers et al., Phys. Rev. B **92**, 014411 (2015)

MA 34.9 Wed 11:45 HSZ 04

Unidirectional short-wavelength spin wave propagation using one-dimensional nanogratings — •Tobias Stückler[1], Jilei Chen[1], Houchen Chang[2], Chuanpu Liu[3], Tao Liu[2], Junfeng Hu[1], Zhe He[1], Weisheng Zhao[1], Zhimin Liao[3], Dapeng Yu[3], Mingzhong Wu[2], and Haiming Yu[1] — [1]Fert Beijing Research Institute, School of electronic and information engineering, Beihang University, Beijing, China — [2]Department of Physics, Colorado State University, Fort Colins, CO, United States — [3]State Key Laboratory for Mesoscopic Physics and Electron Microscopy Laboratory, School of Physics, Peking University, Beijing, China

Utilization of spin waves for information processing has recently seen rapid development. [1] We report spin wave propagation in 1D magnonic nanograting coupler. [2] Nanograting coupler (GC) signals are enhanced compared with conventional antennas which make them a powerful tool for spin wave modulation. Our samples consist of periodic Nickel nanowires grown on nm-thick YIG films with very low Gilbert damping. [3] We use coplanar wave guides to excite and vector network analyzer to detect our signal. Compared to 2D NC [4], we find that 1D NC provoke unidirectional short-wavelength spin waves propagating along the YIG micro-channel and avoid energy losses. References: [1] A. V. Chumak, V. I. Vasyuchka, A. A. Serga, et al, Nature Physics, 11(6), 453-461 (2015). [2] H. Yu, O. A. Kelly, V. Cros, et al, Scientific reports, 4, 6848 (2014). [3] H. Chang, P. Li, W. Zhang, et al, Magnetics Letters, IEEE, 5, 1-4 (2014). [4] H. Yu, G. Duerr, R. Huber, et al, Nature communications, 4, 2702 (2013).

MA 34.10 Wed 12:00 HSZ 04

Interatomic Exchange Interactions for Finite-Temperature Magnetism and Nonequilibrium Spin Dynamics — •Attila Szilva[1], Marcio Costa[1,2,3], Anders Bergman[1], Laszlo Szunyogh[4], Lars Nordström[1], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Instituto de Fisica, Universidade Federal Fluminense, 24210-346 Niteroi, Rio de Janeiro, Brazil — [3]Department of Physics and Astronomy, University of California, Irvine, California 92697, USA — [4]Department of Theoretical Physics and Condensed Matter Research Group of Hungarian Academy of Sciences, Budapest University of Technology and Economics, Budafoki ut 8., H1111 Budapest, Hungary

We derive ab inito exchange parameters for general noncollinear magnetic configurations, in terms of a multiple scattering formalism. We show that the general exchange formula has an anisotropiclike term even in the absence of spin-orbit coupling, and that this term is large, for instance, for collinear configuration in bcc Fe, whereas for fcc Ni it is quite small. We demonstrate that keeping this term leads to what one should consider a biquadratic effective spin Hamiltonian even in the case of collinear arrangement. To illustrate our results in practice, we calculate for bcc Fe magnon spectra obtained from configuration-dependent exchange parameters, where the configurations are determined by finite-temperature effects. Our theory results in the same quantitative results as the finite-temperature neutron scattering experiments.

MA 34.11 Wed 12:15 HSZ 04

Domain configuration mediated spinwave superpositions — •Rasmus B. Holländer, Cai Müller, Mathis Lohmann, and Jeffrey McCord — Institute for Materials Science, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

Spin waves can be generated in close proximity to domain walls [1] or at vortex core centers [2]. Here, we employ time-resolved magneto-optical wide-field imaging in an enhanced concept to directly monitor the local magnetization vector response to an external stimulus in the time domain. Variation of the azimuthal angle of incidence of the probing light yields differential magnetic vector information of the integral signal, allowing for separation of polar and pure in-plane Kerr components. A ferromagnetic resonance geometry utilizing the quasi-homogeneous Oersted-field on top of a coplanar waveguide is used as an excitation scheme. The magneto-dynamic response of an amorphous CoFeB stripe element is investigated in several magnetic domain configurations exhibiting asymetric Bloch walls. The data obtained from different sensitivity directions indicate superpositions of spin waves with wavefronts parallel to the domain walls in a configuration similar to the Damon-Eshbach mode.

The authors thank the German Science Foundation (DFG) for the financial support (grant Mc9/9-2 and Mc9/10-2).
[1] B. Mozooni and J. McCord, APL 107, 042402 (2015)
[2] S. Wintz et al., Nature Nanotech. 11, 948 (2016)

MA 34.12 Wed 12:30 HSZ 04

Electrically Driven Bose-Einstein Condensation of Magnons in Antiferromagnets — Eirik Fjaerbu, •Niklas Rohling, and Arne Brataas — Department of Physics, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway

We explore routes to realize electrically driven Bose-Einstein condensation of magnons in insulating antiferromagnets. Even in insulating antiferromagnets, the localized spins can strongly couple to itinerant spins in adjacent metals via spin-transfer torque and spin pumping [1]. Our model describes a system where a spin accumulation in an adjacent normal metal is aligned with the staggered field of the antiferromagnet. This spin accumulation controls the formation of steady-state magnon condensates. Compared to the earlier proposed ferromagnetic case [2,3], there are two significant differences for antiferromagnets: Firstly, two types of magnons exist in antiferromagnets, which carry opposite magnetic moments. Consequently, Bose-Einstein condensation can occur for either sign of the spin accumulation. Secondly, in antiferromagnets, the operating frequencies of the condensate are orders of magnitude faster than in ferromagnets.

[1] R. Cheng, J. Xiao, Q. Niu, and A. Brataas, Phys. Rev. Lett. **113**, 057601 (2014)
[2] S. A. Bender, R. A. Duine, and Ya. Tserkovnyak, Phys. Rev. Lett. **108**, 246601 (2012)
[3] S. A. Bender, R. A. Duine, A. Brataas, and Ya. Tserkovnyak, Phys. Rev. B **90**, 094409 (2014)

MA 34.13 Wed 12:45 HSZ 04

Femtosecond quantum spin dynamics induced by femto-nanomagnons in Heisenberg antiferromagnets — •Olena Gomonay[1], Davide Bossini[2], Johan Metnik[3], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]University of Tokyo, Japan — [3]Radboud University Nijmegen, Nijmegen, The Netherlands

The major interest of spintronics has recently directed to antiferromagnets which could allow high density storage in a memory device and high frequencies of data processing entering the THz regime.

The use of all-optical schemes opens a way towards the ultrafast manipulation of an antiferromagnets, which up to now was restricted to low-energy magnons at the center of the Brillouin zone. Here we focus on the impulsively generated coherent magnons with the wavevector near the edges of the Brillouin zone – femto-nanomagnons.

We investigate the macrospin dynamics induced by femto-nanomagnons and propose a simple quantum mechanical description of the two-magnon excitation mechanism, based on a light-induced modification of the exchange. We demonstrate that femto-nanomagnonics dynamical regime has purely quantum mechanical nature and that the dynamics is exclusively longitudinal. A complete description of the squeezed-states induced by the femto-nanomagnons is also reported. We also formulate an effective phenomenological theory of the femtosecond longitudinal spin dynamics. We believe that our results pave a way to manipulation and control of squeezed states in the magnetic systems.

MA 35: Magnetic Particles / Clusters

Time: Wednesday 9:30–12:45 Location: HSZ 101

MA 35.1 Wed 9:30 HSZ 101

Direct correlation of microscopic structure and magnetic properties of individual cobalt nanoparticles — •T. M. Savchenko[1], A. Béché[2], M. Timm[1], D. M. Bracher[1], G. Khadra[3], A. Tamion[3], F. Tournus[3], C. Albin[3], V. Dupuis[3], J. Verbeeck[2], F. Nolting[1], and A. Kleibert[1] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland — [2]Electron Microscopy for Materials Science (EMAT), University of Antwerp, Groenenborgerlaan 171, B-2020 Antwerp, Belgium — [3]Institut Lumière Matière, UMR5306 Université Lyon 1-CNRS, Université de Lyon, 69622 Villeurbanne cedex, France

Ever increasing data volumes demand memory devices with higher data storage density. In case of magnetic memory this requires nano-sized units with uniform magnetic properties. However, at the nanoscale a rich structural variety and defects are frequently found in materials which may cause significant dispersion of magnetic properties. A direct correlation of magnetism and atomic composition of nanostructures is so far achieved in spin-polarized scanning tunneling microscopy on surfaces. Here, we present a unique combination of magnetic and microstructural characterization of individual magnetic nanoparticles by means of X-ray photo-emission electron microscopy and high resolution scanning transmission electron microscopy. Distinct magnetic properties are found in cobalt nanoparticles with sizes ranging between 12 and 19 nm irrespective of size and actual microstructure. The results are discussed with respect to defects and morphology.

MA 35.2 Wed 9:45 HSZ 101

Determining anisotropy and magnetic moment of single nanodots from switching time measurements — •Stefan Freercks, Carsten Thönnissen, Eva-Sophie Wilhelm, Philipp Staeck, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Germany

We use the anomalous Hall-effect to investigate the magnetization reversal in single Pt/Co/Pt nanodots (diameter <40nm, Co thickness < 1nm) with perpendicular magnetization. The dots are fabricated by electron beam lithography and ion milling out of thin multilayers [1]. We have investigated the time dependent switching in the superparamagnetic regime and determine the temperature dependence of the switching frequency. The Néel-Arrhenius plot reveals attempt frequencies that deviate from the expected values in the GHz regime [2]. Measuring the occupation as a function of field along the easy axis gives access to the magnetic moment. In the blocked regime a magnetic field is applied perpendicular to the easy axis, which reduces the energy barrier and causes thermal switching. In accordance to experiments in the superparamagnetic regime the switching times are determined as a function of field strength. The field dependent switching times allow for the determination of the dot moment and total anisotropy as a function of temperature. Dots and film reveal a similar temperature behavior. Funding by DFG via SFB 668 is gratefully acknowledged.
[1] A. Neumann *et al.* Nano Letters. **13**, p2199-2203, (2014). [2] Bean and Livingston, J. Appl. Phys. **30**, 120S, (1959)

MA 35.3 Wed 10:00 HSZ 101

Structural and magnetic properties of self-assembled iron oxide nanoparticle films — •Xiao Sun[1], Michael Smik[1], Emmanuel Kentzinger[1], Aladin Ullrich[2], Ulrich Rücker[1], Oleg Petracic[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich — [2]Lehrstuhl für Experimentalphysik II, Universität Augsburg, Augsburg

2D self-assembled iron oxide nanoparticles (NPs) with various sizes (11-20nm) have been studied using magnetometry and Grazing Incidence Small Angle X-ray Scattering (GISAXS). Self-assembled NP films have been fabricated using various methods (e.g. drop-casting/liquid-air-interface) and characterized by scanning electron microscopy and GISAXS. The GISAXS patterns are compared with the simulation results from the software BornAgain[1]. Magnetometry results show an exchange bias effect in hysteresis loops. By comparing hysteresis loops cooled at different magnetic fields, a hardening effect can be observed, i.e. the squareness and hardness of hysteresis loops is significantly enhanced with increasing magnetic cooling field. Due to the antiferromagnetic wustite component, the spins of the ferromagnetic magnetite/maghemite components are exchange biased and an anisotropy axis is induced. The influence of the induced anisotropy onto the magnetic correlations of the magnetic superspins was investigated. The hardening effect of diluted iron oxide NPs is compared to self-assembled NP films. [1]http://bornagainproject.org/

MA 35.4 Wed 10:15 HSZ 101

Structural and magnetic properties of self-assembled 3D nanoparticle macrocrystals — •Michael Smik[1], Genevieve Wilbs[1], Mauricio Cattaneo[1], Elisa Volkmann[1], Emmanuel Kentzinger[1], Stefan Mattauch[2], Jörg Persson[1], Ulrich Rücker[1], Oleg Petracic[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Jülich Centre for Neutron Science JCNS, Heinz Maier-Leibnitz Zentrum, 85747 Garching, Germany

Magnetic nanoparticle assemblies form a novel type of artificial material with properties that are not found in nature. We have succeeded in fabricating large 3D nanoparticle 'macrocrystals' using a novel centrifuge assisted sedimentation technique from commercially available spherical iron oxide nanoparticles. The assembly of macrocrystals up to 300-1000 μm in size was possible. Using small angle x-ray scattering (SAXS) at the new in-house instrument 'GALAXI' (Gallium Anode Low-Angle X-ray Instrument) the supercrystalline structure and quality of ordering could be characterized. The magnetic properties were investigated by a variety of magnetometric methods including zero field cooled and field cooled curves as well as AC susceptibility. For a microscopic investigation of the magnetic ordering, small angle neutron scattering (SANS) was employed at the neutron reflectometer MARIA (MAgnetic Reflectometer with high Incidence Angle) at the Heinz Meier-Leibnitz Zentrum.

MA 35.5 Wed 10:30 HSZ 101

Highly ordered 3D nanoparticle superlattices investigated by microresonator ferromagnetic resonance — •Elisabeth Josten[1,2], Ryszard Narkowicz[1], Attila Kákay[1], Doris Meertens[2], Lennart Bergström[3], Thomas Brückel[2], Kilian Lenz[1], and Jürgen Lindner[1] — [1]Helmholtz-Zentrum Dresden Rossendorf, Dresden, Germany — [2]Forschungszentrum Jülich, Jülich, Germany — [3]Stockholm University, Stockholm, Sweden

Magnetic nanoparticles and their assembly into highly correlated superstructures are of great interest for future applications, e.g. as material for magnon-spintronic. These systems are not only distinguished by the obvious miniaturization but by their novel physical properties. Recently, single micrometer-sized three-dimensional magnetic nanoparticle assemblies became available, exhibiting a high degree of structural order close to that of an atomic crystal. These systems provide a good basis for the magnetic investigation of nanoparticle superstructures. Novel microresonators, provide the necessary sensitivity for the investigation of magnetic properties of nano-objects using ferromagnetic resonance. Due to the much higher filling factor as compared to conventional microwave cavities, they offer several orders of magnitude increased sensitivity gain. A focused ion beam was used to isolate an individual 3D mesocrystal from an ensemble and to transfer it into the microresonator loop. The FMR study reveals the magnetic anisotropy of the single mesocrystal, which is corroborated by micromagnetic simulations. It was possible for us to functionalize the system and to set the magnetic easy axis of the mesocrystal via pre-defining their shape.

MA 35.6 Wed 10:45 HSZ 101

Magnetic properties of Pd and Fe ions in a polyoxopalladate crystal field — •Nataliya Svechkina[1], Natalya Izarova[1], Alevtina Smekhova[1], Detlef Schmitz[2], and Carolin Schmitz-Antoniak[1] — [1]FZ Jülich (PGI-6) — [2]HZB, Berlin

Polyoxometallates (POMs) represent a large class of nanosized, polynuclear metal-oxo anions with a wide compositional and structural variety. Cuboid shaped polyoxopalladates (POPs) shells can incorporate various transitions metal ions placed in the cubic crystal field for studying their magnetic properties. Two types of POPs, Fe-POP (with Fe ion in the center) and Pd-POP (with Pd ion in the center), have been investigated by x-ray absorption spectroscopy (XAS) at the $L_{2,3}$ absorption edges of Fe and at the $M_{2,3}$ absorption edges of Pd. Spin and orbital magnetic moments were quantified by an integral sum-rules analysis of the x-ray magnetic circular dichroism (XMCD).

For Fe-POP, the derived magnetic moments of Fe correspond with the values expected from a simple atomic model. A small XMCD at Pd was found only for the Pd-POP sample. For Fe-POP it is considerably smaller or even absent. This assumes that the magnetism of Pd arises only from the central Pd ion and it is very sensitive to the coordination environment.

In addition, the influence of a hydrogen plasma treatment was investigated. The Fe ions were reduced from the initial $3d^5$ to $3d^6$ state, the crystal field was changed, and no XMCD for Pd was found in both samples.

MA 35.7 Wed 11:00 HSZ 101

Fabrication and characterization of spherical Janus particles with in plane anisotropy exchange bias caps — •Andreea Tomita, Rico Huhnstock, Dennis Holzinger, 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 Janus particles are "dual-faced" particles that can serve multiple purposes at the same time, e.g. one face having magnetic properties, while the other can be functionalized with particular receptors, antibodies, or other enzymes for specific applications.

The system we propose makes use of the multifunctionality of Janus particles and complements them with the novelty of an exchange bias (EB) system deposited as a cap on one of the particle's "faces". The fabrication process is tailored so that the unidirectional anisotropy of the cap is oriented parallel to the surface of the particle. The particles are magnetically characterized via vibrating sample magnetometry (VSM), longitudinal magneto-optical Kerr magnetometry (L-MOKE) and magnetic force microscopy (MFM) and the topological features are investigated by scanning electron microscopy (SEM), respectively. These particles will be then introduced in a transport system for remotely controllable linear and rotatory motion.

MA 35.8 Wed 11:15 HSZ 101

Changing the magnetism of eightfold coordinated 3d transition metal ions in polyoxopalladates by hydrogen plasma — Nataliya Svechkina[1], Natalya V. Izarova[1], Detlef Schmitz[2], Alevtina Smekhova[1], and •Carolin Schmitz-Antoniak[1] — [1]FZ Jülich (PGI-6) — [2]HZB, Berlin

Cuboid-shaped polyoxopalladates hosting either Fe^{3+} ($3d^5$) or Co^{2+} ($3d^7$) ions in their centres have been studied by means of x-ray absorption spectroscopy at the $L_{3,2}$ absorption edges of the 3d elements. While the x-ray absorption near-edge structure (XANES) contains already important information on the valence state, the x-ray magnetic linear dichroism (XMLD) and x-ray magnetic circular dichroism (XMCD) were used to refine the quantification of the crystal field related to the eight oxygen ions surrounding the central ion by comparison with simulations using the CTM4XAS program. In addition, spin and orbital magnetic moments were derived by a sum-rule based analysis of the XMCD.

After a hydrogen plasma treatment, the Fe ions were reduced from the $3d^5$ to a $3d^6$ state while the Co $3d^7$ state remains unaffected. However in both cases, drastic changes of the crystal field and the magnetic properties were obtained pointing to a possible application in nanoscale hydrogen sensing or storage devices.

In addition, data of re-oxidised samples are presented and the influence of different heterogroups stabilising the polyoxopalladates is discussed.

MA 35.9 Wed 11:30 HSZ 101

Transport and rotational dynamics of exchange biased Janus particles in artificial magnetic stray field landscapes — •Rico Huhnstock, Andreea Tomiţa, Dennis Holzinger, 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 investigation of remotely controlled transport of magnetic microparticles above topographically flat substrates is of particular interest for the design of Lab-on-a-chip (LOC) devices, which offer a variety of promising applications in medical diagnostics [1]. In addition to a directed two-dimensional translation of such particles, another degree of freedom for the movement can be found in their rotation properties. In the present study the controlled rotational and translational movement of Janus like colloidal magnetic particles was achieved by the superposition of a static magnetic stray field landscape and a time-dependent external magnetic field sequence. An investigation of the locomotion and the rotational dynamics of the Janus particles was carried out by using tracking and image analysis techniques. The obtained results encourage further experiments for implementing a rotational based transport of the particles and using this method for a biomolecular interaction screening in LOC-applications.

[1] Holzinger, D., Koch, I., Burgard, S., Ehresmann, A. (2015), Directed Magnetic Particle Transport above Artificial Magnetic Domains Due to Dynamic Magnetic Potential Energy Landscape Transformation. ACS Nano, 9: 7323-7331.

MA 35.10 Wed 11:45 HSZ 101

Electronic theory of multicenter complexes as logic elements — •Dibyajyoti Dutta[1], Debapriya Chaudhuri[1,2], Georgios Lefkidis[1], and Wolfgang Hübner[1] — [1]University of Kaiserslautern and Research Center OPTIMAS, Kaiserslautern, Germany — [2]SPINTEC CEA, Grenoble, France

We present a first-principles study of ultrafast spin dynamics on small magnetic Ni/Co clusters. The cooperative effects, due to the electronic correlations and the abundance of *d* electrons, allow the coherent spin manipulation controlled with femtosecond laser pulses [1]. Using already established spin flip and transfer scenarios, one can construct magnetic logic gates.

Previously, we reported results on the synthesis, characterization and suggested laser-induced spin dynamics on ligand-decorated Co_3 and Ni_3 structures [2,3]. Here we extend our study to the $[Co_3Ni]^+$EtOH complex. A high-level *ab initio* calculation suggests a pyramidal structure of the $[Co_3Ni]$ part, in agreement with the spectroscopic data. Our findings suggest that optical spin manipulation in magnetic molecules can be used for future nanospintronic devices.

[1] W. Jin, F. Rupp, K. Chevalier, M. M. N. Wolf, M. Colindres-Rojas, G. Lefkidis, H.-J. Krüger, R. Diller, and W. Hübner, Phys. Rev. Lett. **109**, 267209 (2012)
[2] W. Jin, C. Li, G. Lefkidis, W. Hübner, Phys. Rev. B **89**, 024419 (2014)
[3] D. Chaudhuri, W. Jin, G. Lefkidis, and W. Hübner, J. Chem. Phys. **143**, 174303 (2015)

MA 35.11 Wed 12:00 HSZ 101

Transport of superparamagnetic particles on magnetically structured exchange bias layer systems in microfluidic devices with transversal flow — •Meike Reginka, Dennis Holzinger, Iris Koch, 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 controllable movement of superparamagnetic particles above magnetically stripe-patterned exchange bias (EB) layer systems was used to transport such particles in a microfluidic structure.[1] Transversal flows of defined flux were used to affect the particles' movement perpendicular to the direction of their simultaneous transport. The particle velocities along the flow direction were shown to be 2 to 3 orders of magnitude smaller than the mean fluid velocity due to the transport being located close to the sample surface. The particlesŕtrajectories remain almost unaffected, which allows the purification of biomolecules in microfluidic devices with transversal flow components. Besides that, the effect of the ferromagnetic layer thickness of the EB system was studied for further tailoring of the transport characteristics of superparamagnetic particles by a change of the intrinsic properties of the substrate material.

[1] D. Holzinger, I. Koch, S. Burgard, and A. Ehresmann, ACS Nano 9, 7323 (2015)

MA 35.12 Wed 12:15 HSZ 101

Tuning applied field characteristics to improve efficiency of magnetic hyperthermia — •Oliver Laslett, Hans Fangohr, and Ondrej Hovorka — Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, United Kingdom

The effectiveness of magnetic hyperthermia therapy depends not only upon the material properties of magnetic particles but also on their interaction with one another and their environment. The applied magnetic field is limited in both amplitude and frequency to ensure patient safety and comfort. We investigate the ability of novel waveform shapes to overcome this limit and improve treatment effectiveness. We present multiple theoretical and numerical approaches to simulating the induced power loss in heterogeneous ensembles of magnetic nanoparticles subjected to an arbitrary external field waveform. Crucially, we demonstrate the extent to which linear response theory and transition state theory accurately approximate full simulation of the Langevin dynamics. We also consider the filtering effect of hardware on high frequency switching fields. Subjecting magnetic nanoparticles to non-sinusoidal alternating fields affects the efficacy of treatment and the potential costs of material synthesis. We acknowledge financial support from the EPSRC grant EP/G03690X/1

MA 35.13 Wed 12:30 HSZ 101

The effect of clustering of magnetic nanoparticles on sensing and imaging in medicine — •Ondrej Hovorka — University of Southampton, UK

In this talk we discuss the role of aggregation of magnetic nanoparticles on performance of biosensing methodologies based on magnetorelaxometry (MRX) and of magnetic particle imaging (MPI). Employing the kinetic Monte-Carlo modelling of fractal clusters of magnetic nanoparticles such as typically observed in intracellular environments [1], we show that depending on the structure of aggregates the performance in MRX and MPI can be downgraded or enhanced. We also illustrate various memory effects emerging in the time scale range from superparamagnetic to hysteresis regime and discuss their potential utilisation for optimising the MRX and MPI applications [2, 3]. Understanding the effects of aggregation of magnetic nanoparticles is becoming an increasingly important issue because it implies that optimal designs of magnetic nanostructures need to take into account the considerations of realistic environments.

References: [1] Etheridge et al., Technology 2, 214 (2014). [2] O. Laslett, et al., Applied Physics Letters 106, 012407 (2015). [3] H. Mamiya, B. Jeyadevan, PLoS ONE 10, e0118156 (2015).

MA 36: Transport: Molecular Electronics and Photonics (jointly with CPP, HL, MA, O)

Time: Wednesday 9:30–12:45 Location: HSZ 201

MA 36.1 Wed 9:30 HSZ 201

Negative differential conductance in single-molecule junctions with ferromagnetic electrodes — •Peter Hasch, Yuxiang Gong, Li Jiang, Carlos-Andres Palma, Joachim Reichert, and Johannes V. Barth — Physics Department E20, Technische Universität München, Germany

Scaling down logic operations to the level of single molecules might be considered the next frontier in computation. One approach is to electrically control single spin states in a molecule, trapped between two electrodes.

Here we report the observance of a negative differential conductance (NDC), measured in a single-molecule junction. The investigated NDC could be explained by a single-spin phenomenon, arising when the molecule gets charged due to voltage-induced depopulation of the highest occupied molecular orbital. This oxidation is monitored by Raman spectroscopy, which allows to analyze chemical and electronical structures with a single-molecule sensitivity. By (anti)ferromagnetic coupling of the unpaired spin on the molecule to one of the electrodes, the molecule might act as a spin-valve, blocking charge transport of the opposite spin direction.

Single-molecule NDC elements bear considerable potential for logical crossbar architectures, and could shrink the actual state of the art devices significantly in size.

MA 36.2 Wed 9:45 HSZ 201

Single-molecule junctions with oligoynes and epitaxial graphene nanoelectrodes — •Konrad Ullmann[1], Susanne Leitherer[2], Maximilian Krempe[3], Rik Tykwinski[3], Michael Thoss[2], and Heiko Weber[1] — [1]Lehrstuhl für Angewandte Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany — [2]Institut für Theoretische Physik, Friedrich-Alexander-Universität

Erlangen-Nürnberg, Germany — [3]Organische Chemie I, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Single molecule junctions using graphene as electrode material have drawn considerable attention in recent years [1,2]. Due to their open access architecture, their transparency and robustness, they are well suited for a variety of unprecedented experiments. The electrode material graphene also allows for new anchor groups which connect the molecule to the electrode, e.g. via Pi-interaction.

We report on experiments using an oligoyne molecular wire with platinum termination, being contacted with epitaxial graphene nanoelectrodes. I-V characteristics show a linear behavior with a conductance close to the conductance quantum. Furthermore we present an experimental setup which uses electrospray ionisation to bring the molecules in contact with the graphene electrodes.

[1] K. Ullmann et al., Nano Lett. 15, 3512, 2015
[2] F. Prins et al., Nano Lett. 11, 4607, 2011

MA 36.3 Wed 10:00 HSZ 201

Visualizing the role of molecular orbitals in charge transport through individual diarylethene Isomers — •Gaël Reecht[1], Christian Lotze[1], Dmytro Sysoiev[2], Thomas Huhn[2], and Katharina J. Franke[1] — [1]Freie Universität Berlin , Berlin ,Germany — [2]Universität Konstanz, Konstanz, Germany.

Diarylethene molecules are prototype molecular switches with their two isomeric forms exhibiting strikingly different conductance, while maintaining similar length. With a scanning tunneling microscope (STM) we investigate the electronic structure and the transport properties of the open and closed isomers of a sulfur-free diarylethene. The electronic structure is determined with scanning tunneling spectroscopy (STS) for the molecule lying on the surface. Between the two isomers, intriguing differences of the energy and the spatial extend of the molecule orbitals are observed. We then lift the two isomers with the tip of the STM and measure the current passing through the individual molecules. We observe an important difference of conductance between the two forms. With a simple analytical model of transport based on the results of the STS measurements, we show that the previously determined orbital characteristics are essential ingredients for the complete understanding of the transport properties.

MA 36.4 Wed 10:15 HSZ 201

Electronic transport properties of a tripodal molecular platform — •safa golrokh bahoosh, amin karimi, elke scheer, and fabian pauly — Department of Physics, University of Konstanz, 78457 Konstanz, Germany

Intensive studies on single-molecule junctions have been performed to explore the implementation of molecular-scale devices and to understand how the molecules transport charges[1]. While molecules with delocalized π-systems are the ideal compounds to form wires for electronic applications due to their expected high conductance, tripodal molecular platforms that points almost perpendicular to the surface, appear as promising candidates to establish a conducting path between two electrodes. To take into account these aspects, a 9,9'-spirobifluorene (SBF) platform has been introduced. By combining experimental and theoretical investigations of elastic and inelastic charge transport, we show that the current proceeds through the molecular "backbone" and identify a binding geometry that is compatible with the experimental observations in mechanically controlled break junctions[2]. The conductive molecular wire on the platform features a well-defined and relatively high conductance despite the length of the current path of more than 1.7 nm. If time permits, the possibility to use these molecules as a molecular toggle switch, as observed in subsequent studies with a scanning tunneling microscope, will be discussed.

[1] S. Aradhy, and L. Venkataraman, Nature Nanotechnol. 8, 399 (2013)
[2] M. A. Karimi, S. G. Bahoosh, M. Valášek, M. Bürkle, M. Mayor, F. Pauly, and E. Scheer, Nanoscale 8, 10582 (2016)

MA 36.5 Wed 10:30 HSZ 201

Analysis of local current through molecular wires in open quantum systems — •Daijiro Nozaki, Andreas Lücke, and Wolf Gero Schmidt — Lehrstuhl für Theoretische Materialphysik, Universität Paderborn, 33095 Paderborn, Germany

The understanding of the local electronic flows in single molecules is of fundamental importance in the design of functional molecules as well as molecule-based electronic devices [1-4]. The charge transport through molecular wires connected between contacts is investigated using non equilibrium Green's function formalism combined with Landauer formula. Energy-dependent and total current through a series of molecular junctions are calculated in real space representation. The influence of contact positions, functional groups, and the replacement of atoms as defects on the transport properties are examined systematically. The static current-induced local magnetic field is also investigated in carbon-based molecular wires. It is shown that even in the same bias directions the direction of the magnetic field is easily reversed depending on the molecular topologies and the positions of electric contacts.

[1] M. Walz, J. Wilhelm, and F. Evers Phys. Rev. Lett. **113**, 136602 (2014)
[2] J. Wilhelm, M. Walz, and F. Evers Phys. Rev. B **92**, 014405 (2015)
[3] G. C. Solomon, C. Herrmann, T. Hansen, V. Mujica, and M. A. Ratner Nat. Chem. **2**, 223 (2010)
[4] T. Ono and K. Hirose, Phys. Rev. Lett. **98**, 026804 (2007)

MA 36.6 Wed 10:45 HSZ 201

Controlling the conductance of graphene-molecule junctions by proton transfer — •Dominik Weckbecker, Pedro B. Coto, and Michael Thoss — FAU Erlangen-Nürnberg, Institut für Theoretische Physik, Staudtstrasse 7/B2, 91058 Erlangen, Germany

The possibility of using single-molecule junctions as components of nanoelectronic devices has motivated intensive experimental and theoretical research on the underlying transport mechanism in these systems [1]. In this contribution, we investigate from a theoretical perspective intramolecular proton transfer reactions as a mechanism for controlling the conductance state of graphene-based molecular junctions. Employing a methodology that combines first-principles electronic structure calculations with nonequilibrium Green's function transport theory [1], we show that the proton transfer reaction proceeds via a two-step mechanism and gives rise to several states of the junction with different conductance properties. In addition, we demonstrate that the relative stability of the different conductance states and the energy barriers for the interconversion reactions can be controlled by means of an external electrostatic field. The possibility of using this mechanism for the design of nanomolecular devices such as diodes or switches is also discussed [2,3].

[1] Cuevas, J. C. and Scheer, E., Molecular Electronics, World Scientific Pub. Co., Singapore, 2010
[2] Hofmeister, C. *et al.*, J. Mol. Model. **20**, 2163 (2014)
[3] Hofmeister, C. *et al.*, arXiv: 1611.01027v1 (2016)

15 min. break.

MA 36.7 Wed 11:15 HSZ 201

Hierarchical Quantum Master Equation Approach to Vibrationally Coupled Nonequilibrium Charge Transport in Single-Molecule Junctions — •Christian Schinabeck[1], André Erpenbeck[1], Rainer Härtle[2], and Michael Thoss[1] — [1]Institut für Theoretische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany. — [2]Institut für Theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany.

We investigate vibrationally coupled transport in single-molecule junctions using the hierarchical quantum master equation (HQME) approach [1-3]. This method allows a systematic convergence of the reduced dynamics of open quantum systems beyond the traditional perturbative master equations. We demonstrate the importance of vibrational nonequilibrium effects for a model molecular junction consisting of an electronic level coupled to fermionic leads as well as a vibrational mode. In particular, in the off-resonant transport regime, the inelastic cotunneling signal is analyzed for a vibrational mode in full nonequilibrium, revealing a complex interplay of different transport processes and deviations from the commonly used $G_0/2$ rule of thumb [3]. Moreover, an extension of the HQME approach is presented, which allows the calculation of the full counting statistics. Using this method, the influence of higher-order cotunneling processes on the current fluctuations is analyzed.

[1] Y. Tanimura *et al.*, J. Phys. Soc. Jpn. **75**, 082001 (2006).
[2] J. Jin *et al.*, J. Chem. Phys. **128**, 234703 (2008).
[3] C. Schinabeck *et al.*, Phys. Rev. B **94**, 201407 (2016).

MA 36.8 Wed 11:30 HSZ 201

Theoretical study of current-induced bond rupture in molecular junctions — •André Erpenbeck, Christian Schinabeck, Lukas Götzendörfer, and Michael Thoss — Institut für Theoretische Physik und Interdisziplinäres Zentrum für Molekulare Mate-

rialien (ICMM), Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7/B2, D-91058 Erlangen, Germany

Electronic-vibrational coupling in charge transport through single molecule junctions may result in current-induced bond rupture and is thus an important mechanism for the stability of the junction. In this contribution, we demonstrate how the hierarchical quantum master equation (HQME) theory in combination with the quasi-classical Ehrenfest approach for the nuclear degrees of freedom can be used to simulate current-induced bond rupture in single molecule junctions. Employing generic models for molecular junctions with dissociative nuclear potentials, we analyze the underlying mechanisms. In particular, we investigate the dependence of the current, the population and the dissociation probability on the model parameters. In addition, we validate the quasi-classical Ehrenfest approach using numerically exact results obtained by the HQME method [1] for a model comprising one harmonic vibrational mode.

[1] C. Schinabeck, A. Erpenbeck, R. Härtle, M. Thoss, Phys. Rev. B 94, 201407(R) (2016)

MA 36.9 Wed 11:45 HSZ 201

Spin Transport in Helical Systems — •Matthias Geyer[1,2], Rafael Gutiérrez[1], Stefan Siegmund[3], and Gianaurelio Cuniberti[1,2] — [1]Institute for Materials Science, TU Dresden, 01062 Dresden, Germany — [2]Dresden Center for Computational Materials Science, TU Dresden, 01062 Dresden, Germany — [3]Center for Dynamics, TU Dresden, 01062 Dresden, Germany

Various experiments have shown strong spin selectivity in chiral molecules like DNA at room temperature. Since atomic spin orbit coupling alone is insufficient to explain the effect's magnitude, a relation to the helical geometry has been suggested. We want to provide a better understand of the underlying mechanisms by analytically and numerically investigating suitable models for electrons in helical systems with spin orbit coupling.

We follow two complementary approaches: a generic and simplified model to study the bare influence of the helical geometry and a more realistic one to calculate the effect for specific molecules. The former starts with a 3D continuum model with helix-shaped confinment from which an effective 1D Hamiltonian is derived using adiabatic perturbation theory. For the ladder an effective tight-binding model is derived from the microscopic Hamiltonian of a specific molecule. Incoherent transport calculations are performed for both models using master equations with dephasing, accounting for decoherence due to the coupling to vibrational degrees of freedom arising from structural fluctuation.

MA 36.10 Wed 12:00 HSZ 201

Charge Carrier Dynamics in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl: From Mott Insulator to Quantum Spin Liquid — •Jana-Isabelle Polzin[1], Benedikt Hartmann[1], Takahiko Sasaki[2], and Jens Müller[1] — [1]Institute of Physics, Goethe University Frankfurt, Germany — [2]Institute for Materials Research, Tohoku University, Sendai, Japan

The organic charge transfer salts κ-(ET)$_2$X are model systems for studying strongly-correlated charge carriers and the Mott metal-insulator transition in reduced dimensions. Recently, the influence of quenched disorder attracted considerable attention. Conducting layers of ET molecules are separated by thin, insulating sheets with anions X, resulting in a quasi-2D electronic band structure. Within the ET layers the molecules are arranged in dimers forming a triangular lattice. One free charge carrier exists per dimer, its spin being geometrically frustrated. The Mott insulator κ-(ET)$_2$Cu[N(CN)$_2$]Cl shows antiferromagnetic ordering at $T_N \approx 27\,K$. It has been shown that increasing disorder induced by X-ray irradiation drives the Mott insulating state with long-ranged antiferromagnetic order into a quantum spin liquid state [1]. Here, we discuss comparative measurements of fluctuation spectroscopy on pristine and irradiated samples in order to investigate the changes in electronic transport mechanism and low-frequency charge carrier dynamics [2] when tuning the Mott insulator to the spin liquid ground state. This results in a decrease of both resistivity and the current or voltage fluctuations after irradiation.

[1] PRL 115, 077001 (2015)
[2] PRL 114, 216403 (2015)

MA 36.11 Wed 12:15 HSZ 201

Charge Carrier Dynamics at the Mott transition in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br — •Tatjana Thomas[1], Benedikt Hartmann[1], Takahiko Sasaki[2], and Jens Müller[1] — [1]Institute of Physics, Goethe University Frankfurt, Germany — [2]Institute for Materials Research, Tohoku University, Sendai, Japan

The organic charge transfer salts κ-(ET)$_2$X are considered as model systems for studying the Mott metal-insulator transition – a key phenomenon in the physics of strongly correlated electrons – in reduced dimensions. In particular, the influence of disorder on the criticality of the Mott transition recently has been a matter of debate. Partially deuterated κ-[(H$_8$-ET)$_{0.2}$(D$_8$-ET)$_{0.8}$]$_2$Cu[N(CN)$_2$]Br, which is located in the critical region of the phase diagram, can be fine-tuned through the Mott transition by utilizing a glass-like structural ordering transition of the ET molecules' terminal ethylene groups. By applying different thermal relaxation protocols, both the ratio of W/U and a small degree of quenched disorder can be set at will, the former corresponding to changes in hydrostatic pressure of $\sim 200\,$bar. We employ fluctuation (noise) spectroscopy as a powerful tool to study the charge carrier dynamics at low frequencies. When crossing the S-shaped Mott transition line, surprisingly we observe a step-like increase of the resistance fluctuations in the metallic region. We discuss our results in terms of critical slowing down of the order parameter fluctuations [1] and electronic phase separation, and an extended region of the phase diagram where the fluctuations are non-Gaussian.

[1] B. Hartmann et al., *Phys. Rev. Lett.* **114**, 216403 (2015).

MA 36.12 Wed 12:30 HSZ 201

Thermal conductance of Teflon and Polyethylene: Insight from an atomistic, single-molecule level — •Marius Buerkle and Yoshihiro Asai — AIST, Tsukuba, Japan

The thermal transport properties of teflon (polytetrafluoroethylene) and its polyethylene counterparts are, while highly desirable and widely used, only superficially understood. Here, we aim therefore to provide rigorous insight from an atomistic point of view in context of single-molecule devices. We show that for vinyl polymers adsorbed on metal-surfaces the thermal transport strongly depends one the properties of the metal-molecule interface and that the reduced thermal conductance observed for teflon derivatives originates in a reduced phonon injection life time. In asymmetric molecules phonon blocking on the intra molecular interface leads to a further reduction of thermal conductance. For hetrojunctions with different electrode materials we find that thermal conductance is suppressed due to a reduced overlap of the available phonon modes in the different electrodes. A detailed atomistic picture is thereby provided by studying the transport through perfluorooctane and octane on a single-molecule level using first principles transport calculations and nonequilibrium molecular dynamic simulations.

MA 37: Micro- and Nanostructured Magnetic Materials

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

MA 37.1 Wed 9:30 HSZ 401

Ferromagnetic resonance spectroscopy of magnetotactic bacteria — •Sara Ghaisari[1], Michael Winklhofer[2], Stefan Klumpp[3], and Damien Faivre[1] — [1]Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany — [2]School of Mathematics and Science, University of Oldenburg, Oldenburg, Germany — [3]Institute for Nonlinear Dynamics, Georg-August University Göttingen, Göttingen, Germany

Magnetotactic bacteria represent an example of a simple biomineralizing organism that synthesizes inorganic nanoparticles called as magnetosomes. Magnetosomes consist of a lipid membrane surrounding a ferrimagnetic crystal, which typically is magnetite Fe3O4 or greigite Fe3S4, with a size (40-100 nm). The particles are organized by some protein structures in a chain form inside the cells. Genetic manipulations enable the cell to produce other particle arrangements like e.g. clusters. Due to unique magnetic and morphologic properties, magnetosome particles and their functionality are attracting broad interest in many interdisciplinary areas.

Ferromagnetic Resonance (FMR), as a powerful tool for determining the magnetic anisotropies, is used in this study to explore the magnetic properties of the magnetosomes in different strains. Magnetic uniaxial and crystalline anisotropies of the different morphologies are calculated. Besides, by modeling the chain imperfections and alignment statistics through a Fisher distribution function, along to analyzing the geometry of magnetosome configuration, statistical interpretations of the bulk sample have been achieved.

MA 37.2 Wed 9:45 HSZ 401

Magnetization dynamics of a single Fe-filled carbon nanotube detected by ferromagnetic resonance — •Kilian Lenz[1], Ryszard Narkowicz[1], Christopher F. Reiche[2], Attila Kákay[1], Thomas Mühl[2], Bernd Büchner[2], Dieter Suter[3], Jürgen Fassbender[1,4], and Jürgen Lindner[1] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstr. 400, 01328 Dresden — [2]Leibniz Institute for Solid State and Materials Research IFW Dresden, Helmholtzstr. 20, 01069 Dresden — [3]Department of Physics, TU Dortmund, 44221 Dortmund — [4]TU Dresden, 01062 Dresden

The precise magnetic characterization of a single nanostructure by e.g. ferromagnetic resonance is an experimental challenge as they lack the necessary sensitivity to measure single sub-micron-sized structures. Measurements of arrays of such elements are no alternative due to inhomogeneity. Microresonator FMR [1] can overcome these limitations boosting the FMR sensitivity by several orders of magnitude. Thus a single Fe-filled carbon nanotube (Fe-CNT) of 42 nm diameter [2] can be measured. A focused ion beam was used to shorten little-by-little the length of the Fe-CNT after each FMR measurement. Angle-dependent FMR measurements were performed to extract the anisotropy contributions. The narrow linewidth suggests that the Fe-filling is a well ordered crystal as confirmed by TEM. Supported by DFG MU1794/3-2. [1] A. Banholzer et al., Nanotechnology **22**, 295713 (2011) [2] P. Banerjee et al., Appl. Phys. Lett. **96**, 252505 (2010).

MA 37.3 Wed 10:00 HSZ 401

Magnetic nanoparticles as building blocks for hierachically designed samples to investigate collective magnetic phenomena — •Alexander Fabian[1], Matthias T. Elm[1,2], Detlev M. Hofmann[1], and Peter J. Klar[1] — [1]I. Physikalisches Institut, Heinrich-Buff-Ring 16, 35392 Giessen — [2]Physikalisch-Chemisches Institut, Heinrich-Buff-Ring 17, 35392 Giessen

Almost all magnetic phenomena are based on collective interaction of the electrons of the material. The magnetic characteristics of a material such as its hysteresis behavior, is determined by the macroscopic shape of the ferromagnet or the formation of domains. To deepen the understanding of magnetic interactions on different length scales we use nanoparticles as larger building blocks than atoms, which are ordered in hierachically assemblies. Besides from a fundamental view this is interesting for applications, e. g. in high density storage media and spin tronic devices. We describe how spherical magnetite nanoparticles with a diamater of $d = 20$ nm can be assembled in hierachical structures. For this purpose we use a top-down lithographic method combined with the meniscus force deposition method. Characterization is done by angle-dependent ferromagnetic resonance measurements. The results show that on the chosen length scales only the shape of the nanoparticle assemblies determine the magnetic behavior. Moreover the experimental results are accompanied by a theoretical model based on the Smit-Suhl formalism and by micromagnetic calculations to characterize the possible formation of domains in the assemblies.

MA 37.4 Wed 10:15 HSZ 401

Dimension and shape dependence of magnetization reversal mechanisms and magnetic anisotropies in four-fold nanomagnets — •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, Gliwice, Poland

Magnetic nanoparticles are intensively investigated due to their intriguing magnetic properties, such as a broad variety of magnetization reversal mechanisms and unusual anisotropies. Especially fourfold nanowire structures were shown to exhibit technologically interesting magnetic properties - they may show a step in the hysteresis loop correlated with a stable intermediate state at remanence which can be utilized in quaternary memory cells. Magnetization reversal mechanisms and the possible existence of such stable intermediate states, however, depend strongly on the materials, dimensions, and exact shapes of the nanoparticles under investigation.

In a recent project, fourfold nanoparticles of different dimensions and shape modifications were modeled using typical properties of permalloy, iron, and cobalt. In these systems, different numbers of stable intermediate states were found in different angular orientations. For cobalt, the largest number of steps was simulated, while coercive fields showed an irregular and unpredictable behavior.

In all cases, comparisons with previous calculations underlined that common mathematical descriptions of fourfold magnetic systems are no longer valid in the investigated nanoparticles.

MA 37.5 Wed 10:30 HSZ 401

Influence of dipolar coupling on microstructured multilayer giant magnetoimpedance (GMI) sensors in the high frequency regime — •Gregor Büttel and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

We have fabricated microstructured GMI sensors integrated into a coplanar waveguide consisting of a Cu core layer (250nm thickness) surrounded by magnetic Permalloy single and multilayers. This leads to different and complex coupling behavior of the layers and strongly influences important parameters like maximum GMI ratio, sensitivity and it creates additional peaks in the GMI curve which is in contrast to thin film devices in the mm regime about which was reported so far. To better tune and analyze such devices we have combined MOKE microscopy and micromagnetic simulations to understand the role of dipolar coupling and multi-domain switching. We discuss the complex phenomenology of domain structures for such GMI Py multilayer microstructures. This could so far not be supported by high-resolution domain-imaging techniques. Additionally we fabricated arrays of such microstructured multilayers that allow for recording of the hysteresis curve in a vibrating sample magnetometers and full magnetic characterization in order to understand the coupling behaviour in multilayers with odd and even number of magnetic layers.

MA 37.6 Wed 10:45 HSZ 401

Structural and magnetic characterizations of highly ordered arrangements of magnetic nanoparticles — •Asmaa Alhroob[1], Emmanuel Kentzinger[1], Marina Ganeva[2], Dominique Dresen[3], Sabrina Disch[3], Juergen Moers[4], Jun Xu[5], Giuseppe Portale[5], Xiao Sun[1], Oleg Petracic[1], Ulrich Ruecker[1], and Thomas Brueckel[1] — [1]Jülich Centre for Neutron Science (JCNS) and Peter Grünberg Institute (PGI), JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Jülich Centre for Neutron Science, Forschungszentrum Jülich, Outstation at MLZ, 85748 Garching, Germany — [3]Departments of Chemistry, University of Cologne, 50939 Cologne, Germany — [4]Helmholtz Nanoelectronic Facilities (HNF) and Peter Grünberg Institute (PGI) Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [5]Zernike Institute for Advanced Materials, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Long range ordering between magnetic nanoparticles in two and three-dimensions is obtained by assisted self-assembly using pre-patterned substrates with feature size of the same order of magnitude as the diameter of the nanoparticles.

In this contribution, we will report on the first steps of this program, that are the structural characterization of patterned silicon substrates by Grazing Incidence Small Angle X-ray Scattering (GISAXS) on the laboratory high brilliance GALAXI instrument with data analysis using the BornAgain software and the structural and magnetic characterizations of monolayers of CoFe2O4 nanoparticles.

15 min. break.

MA 37.7 Wed 11:15 HSZ 401

Influence of domain wall substructures on magnetic energies of patterned Permalloy films — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Germany

Substructures of domain walls (such as Bloch points, Bloch lines, Neel lines and vortex-antivortex pairs) significantly affect the magnetic characteristics of patterned magnetic materials [1, 2]. We have investigated the influence of domain wall substructures on magnetic energies of Permalloy (Ni80Fe20) patterned thin films. The microstructured patterned films in the thickness range of 20 nm to 150 nm were investigated. The single-vortex state was observed as the lowest energy state for square patterns, while various lowest energy states for rectangular patterns were observed for different film thicknesses. Energy density for the lowest energy configuration decreases with an increase of the patterned structure thickness.

[1] A. Hubert and R. Schäfer, Magnetic domains, Springer (1998)
[2] V.V. Zverev et al., Phys. Solid State, 56, 1785 (2014)

MA 37.8 Wed 11:30 HSZ 401

Collective oscillations of magnetic vortices — •Max Hänze[1,2,3], Benedikt Schulte[1,3], Christian F. Adolff[3,4], Markus Weigand[5], and Guido Meier[1,3,4] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Institut für Angewandte Physik, Universität Hamburg — [4]The Hamburg Centre for Ultrafast Imaging, Hamburg — [5]Max-Planck-Institut für Intelligente Systeme, Stuttgart

Tailored ferromagnetic structures on micro- to nanometer length scales are promising candidates for future storage and logic devices based on spin-wave excitations. We study collective oscillations of coupled magnetic vortices emerging in micron-sized permalloy disks using two complementary measurement techniques, i.e., scanning transmission X-ray microscopy and ferromagnetic resonance spectroscopy.

Coupled magnetic vortices can exhibit crystal properties, e.g. a dispersion relation and a group velocity [1]. The manipulation of such properties is demonstrated on nanosecond time scales [2] using the excitation of coupled gyrotropic motions and coupled spin-wave modes in closely packed vortex arrangements [3,4].

[1] C. Behncke, M. Hänze, C. F. Adolff, M. Weigand, and G. Meier, Phys. Rev. B 91, 224417 (2015) [2] M. Hänze, C. F. Adolff, M. Weigand, and G. Meier, Phys. Rev. B 91, 104428 (2015) [3] M. Hänze, C. F. Adolff, B. Schulte, J. Möller, M. Weigand, and G. Meier, Sci. Rep. 6, 22402 (2016) [4] M. Hänze, C. F. Adolff, S. Velten, M. Weigand, and G. Meier, Phys. Rev. B 93, 054411 (2016)

MA 37.9 Wed 11:45 HSZ 401

Programmable magnetization configurations in Co-antidot lattices of optimized geometry — Tobias Schneider[1,2], Manuel Langer[1,3], Julia Alekhina[1,4], Ewa Kowalska[1,3], Antje Oelschlägel[1,3], Anna Semisalova[1,4], Andreas Neudert[1], Kilian Lenz[1], Mikhail P. Kostylev[5], Jürgen Fassbender[1,3], Adekunle O. Adeyeye[6], Jürgen Lindner[1], and •Rantej Bali[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]Technische Universität Chemnitz, Germany — [3]Technische Universität Dresden, Germany — [4]Lomonosov Moscow State University, Russia — [5]University of Western Australia, Australia — [6]National University of Singapore, Singapore

Programmable stable magnetization configurations are of great interest for the emerging fields of spintronics and magnonics. Such devices might act as spinwave filters or spinwave logics. Here, we present a micromagnetic study of the reversal process in Cobalt antidot lattices. To achieve stable magnetization configurations we optimized the thickness and the inter-antidot distance, resulting in ≈ 50 nm and respectively ≈ 150 nm . The magnetization reversal in these antidots occurs via field driven transition between 3 elementary magnetization states - termed G, C and Q . These magnetization states can be described by vectors, and the reversal process proceeds via step-wise linear operations on these vector states. The reversal processes predicted by micromagnetic simulations were confirmed by experimental observations.

MA 37.10 Wed 12:00 HSZ 401

Collective dynamics in square artificial spin ice — •Spiridon D. Pappas[1], Mikael S. Andersson[2], Henry Stopfel[1], Agne Ciuciulkaite[1], Erik Östman[1], Aaron Stein[3], Per Nordblad[2], Roland Mathieu[2], Björgvin Hjörvarsson[1], and Vassilios Kapaklis[1] — [1]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden. — [2]Department of Engineering Sciences, Uppsala University, Box 534, SE-751 21 Uppsala, Sweden. — [3]Center for Functional Nanomaterials, Brookhaven National Laboratory, P.O. Box 5000, Upton, NewYork 11973, USA.

Recent advances in nanolithography allow the study of collective response and dynamics of interacting artificial assemblies of mesoscopic spins. In this work, we study the thermally induced magnetic relaxation process, as well as the temporal dynamics, in square Artificial Spin Ice (ASI) [1]. The time dependent magnetization of square ASI was recorded by using time-resolved magnetometry and the temporal dynamics were probed via MOKE susceptibility. The results provide: (a) a clear manifestation of cooperative behavior in the square ASI arrays, (b) proof that the relaxation behavior of the arrays can be tuned by adjusting the interaction strength between the magnetically interacting building blocks (c) a deep insight into the relaxation dynamics of mesoscopic nano-magnetic model systems, with adjustable energy and time scales, and (d) a clear demonstration that square ASI systems can be used as a new type of model system for the study of collective dynamics and relaxation phenomena in magnetic nanosystems. [1] M. S. Andersson et al., Scientific Reports 6, 37097 (2016).

MA 37.11 Wed 12:15 HSZ 401

Mesoscale Dzyaloshinskii-Moriya interaction — •Oleksii Volkov[1,2], Denis Sheka[3], Denys Makarov[1], Jürgen Fassbender[1], Volodymyr Kravchuk[2], and Yuri Gaididei[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine — [3]Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

A broken chiral symmetry in a magnetic system can lead to the appearance of both periodical and localized magnetization structures. The spin-orbit driven Dzyaloshinskii-Moriya interaction (DMI), which is intrinsic to the crystal, is the origin of all those magnetic textures [1]. Recently, we reported [2,3] that geometrically broken symmetry in curvilinear magnetic systems also leads to the appearance of shape-induced effective DMI.

The combined intrinsic and shape-induced DMI can be reffered to as a mesoscale DMI, whose symmetry and strength depend on the geometrical and material parameters. The mesoscale DMI determines chiral properties of curved systems. We derive the general expression for the mesoscopic DMI terms and determined the conditions for periodical magnetisation structures to appear in one-dimensional ferromagnetic helix wires.

[1] A. Soumyanarayanan et. al., *Nature* **539**, 509-517 (2016).
[2] Y. Gaididei et. al, *Phys. Rev. Lett.* **112**, 257203 (2014).
[3] D. D. Sheka et. al., *J. Phys. A: Math. Theor.* **48**, 125202 (2015).

MA 38: Electron Theory of Magnetism and Correlations

Time: Wednesday 9:30–12:15 Location: HSZ 403

MA 38.1 Wed 9:30 HSZ 403

Large coercivity fields and magnetic anisotropy in $Li_2Sr[(Li_{1-x}Fe_x)N]_2$ — •Tanita Johanna Ballé[1], Peter Höhn[2], and Anton Jesche[1] — [1]EP VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86159 Augsburg, Germany — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

$Li_2(Li_{1-x}Fe_x)N$ is the material with the highest known coercivity field with a value of more than 11 T and shows huge magnetic anisotropy. These properties are attributed to an orbital contribution to the magnetic moment of iron that is unquenched due to the perfect linear, twofold coordination of iron between nitrogen [1]. $Li_2Sr[(Li_{1-x}Fe_x)N]_2$ provides a similar geometry. In order to evaluate the necessity as well as sufficiency of the linear, twofold coordination for the high coercivity field and anisotropy to emerge, we investigated single crystals of $Li_2Sr[(Li_{1-x}Fe_x)N]_2$ with $x = 0.41$. A thorough structural characterization was carried out by means of powder and single crystal X-Ray diffraction as well as chemical analysis. Isothermal and temperature dependent magnetization measurements were performed in the range of $T = 2$ K - 300 K and applied fields of up to $\mu_0 H = 7$ T. A coercivity field of almost 7 T at 2 K and a high magnetic anisotropy were indeed observed. Furthermore we found an enhanced magnetic moment and magnetic susceptibility in this material that indicate a significant orbital contribution to the magnetic moment of iron. [1] A. Jesche *et al.*, Nat. Commun. **5**:3333. doi: 10.1038/ncomms4333 (2014)

MA 38.2 Wed 9:45 HSZ 403

Bilinear and higher order exchange couplings in condensed matter physics by multiple-parameter perturbation theory — •Danny Thonig[1], Pavel Bessarab[2], Lars Bergqvist[2], Manuel Pereiro[1], Anna Delin[2], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, University Uppsala, Sweden — [2]Department of Materials and Nano Physics, KTH, 16440 Kista, Sweden

A profound concept in theoretical modelling is epitomised by the mapping of total energy variations on effective Hamiltonians. For instance, bilinear couplings describe well the interaction between atomistic magnetic moments (Heisenberg model) or lattice vibrations (force constant matrix)[1]. Nevertheless, these models are inconsistent at finite temperature and call for a full description.

We will present our multiple-parameter perturbation approach based on first principles method and its realisation in the real-space Slater-Koster parametrised Tight Binding method. Thermal, chemical or occupational disorder are considered as average in real space.

The current method will be applied to bulk Stoner magnets. Zero temperature bilinear coupling parameters are well reproduced, but finite temperature gives significant changes in the magnitude and long-range character. We will present new types of couplings, e.g. bilinear spin-lattice or orbital moment coupling, and a generalisation for higher-orders. Our results give a fundamental new insight into coupling mechanism in condensed matter physics.

[1] V. Vitek and D. J. Srolovitz, "Atomistic Simulation of Materials: Beyond Pair Potentials" Plenum Press, New York (1989)

MA 38.3 Wed 10:00 HSZ 403

The frozen magnon method beyond the long-wave approximation — •Adam Jakobsson — Luleå University of Technology, Luleå, Sweden

The magnetic force theorem provides convenient ways to study exchange interactions in magnetic systems since it gives access to total energy differences between different magnetic states from non-self-consistent density functional theory calculations. This enables the efficient mapping of the total energy of the system as a function of the directions of the atomic moments in a Heisenberg model. However, it is well known that short range interactions in itinerant magnetic systems are poorly described with the conventional use of the theorem. In order to overcome this deficiency, numerous strategies have been developed over the years. We propose a two-step procedure and show that only by adding pre-converged constraining fields to non-self-consistent spin-spiral total energy calculations we obtain results that match self-consistent calculations. With this procedure, we can now do frozen magnon calculations which go beyond the long-wave approximation and thus properly describe the energy landscape of itinerant magnets. As a consequence only the exchange parameters from the non-self-consistent two-step procedure are in quantitative agreement with self-consistently derived exchange parameters. We exemplify this for three different systems: bcc Fe, fcc Ni and FeCo.

MA 38.4 Wed 10:15 HSZ 403

Staircase of crystal phases of hard-core bosons on the kagome lattice — •Daniel Huerga[1], Sylvain Capponi[2], Jorge Dukelsky[3], and Gerardo Ortiz[4] — [1]Institut fur Physik Theorique III, Stuttgart, Germany — [2]Laboratoire de Physique Theorique CNRS, Toulouse, France — [3]Instituto de Estructura de la Materia CSIC, Madrid, Spain — [4]Physics Department Indiana University, Bloomington IN, USA

We study the quantum phase diagram of a system of hard-core bosons on the kagome lattice with nearest-neighbor repulsive interactions, for arbitrary densities, by means of the hierarchical mean-field theory and exact diagonalization techniques. This system is isomorphic to the spin S=1/2 XXZ model in presence of an external magnetic field, a paradigmatic example of frustrated quantum magnetism. In the non-frustrated regime, we find two crystal phases at densities 1/3 and 2/3 that melt into a superfluid phase when increasing the hopping amplitude, in semiquantitative agreement with quantum Monte Carlo computations. In the frustrated regime and away from half-filling, we find a series of plateaux with densities commensurate with powers of 1/3. The broader density plateaux (at densities 1/3 and 2/3) are remnants of the classical degeneracy in the Ising limit. For densities near half-filling, this staircase of crystal phases melts into a superfluid, which displays finite chiral currents when computed with clusters having an odd number of sites. Both the staircase of crystal phases and the superfluid phase prevail in the noninteracting limit, suggesting that the lowest dispersionless single-particle band may be at the root of this phenomenon.

MA 38.5 Wed 10:30 HSZ 403

Ab-initio calculations of QMOKE in bcc Fe, Drude term modelling — •Ondřej Stejskal[1], Robin Silber[1,2], Jaroslav Hamrle[3], Martin Veis[3], and Jaromír Pištora[1] — [1]VSB-Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University, Prague, Czech Republic

The part of the magnetooptic Kerr effect (MOKE) that is even in magnetization is called the quadratic MOKE (QMOKE). Permittivity tensor fully describes the magnetooptic response of a material. We performed ab-initio calculations of the permittivity tensor in bcc Fe by the WIEN2k code [1]. We also model the intraband contributions via the Drude term [2]. The results are then compared to experiment. This work further includes detailed investigation of key bands contributing to the MOKE signal and their visualisation in Brillouin zone.

[1] P. Blaha, K. Schwarz, G. Madsen, D. Kvasnicka and J. Luitz, WIEN2k

[2] Š. Višňovský, Optics in Magnetic Multilayers and Nanostructures, Taylor and Francis Group, Boca Raton, Florida 2006

15 min. break.

MA 38.6 Wed 11:00 HSZ 403

Coherence and stiffness of spin waves in diluted ferromagnets — •Ilja Turek[1], Josef Kudrnovsky[2], and Vaclav Drchal[2] — [1]Institute of Physics of Materials, Acad. Sci. Czech Rep., Brno, Czech Republic — [2]Institute of Physics, Acad. Sci. Czech Rep., Prague, Czech Republic

We present results of a numerical analysis of magnon spectra in supercells simulating low-dimensional and bulk random diluted ferromagnets with long-ranged pair exchange interactions [1]. We show that low-energy spectral regions for these strongly disordered systems contain a coherent component leading to interference phenomena manifested by a pronounced sensitivity of the lowest excitation energies to the adopted boundary conditions. The dependence of configuration averages of these excitation energies on the supercell size can be used for an efficient determination of the spin-wave stiffness D. The developed formalism is applied to the ferromagnetic Mn-doped GaAs semiconductor with optional incorporation of phosphorus; the obtained concentration trends of D are found in reasonable agreement with recent experiments. Moreover, a relation of D to the Curie temperature has been studied for Mn-doped GaAs and GaN semiconductors.

[1] I. Turek et al., arXiv: 1611.06691 (2016).

MA 38.7 Wed 11:15 HSZ 403

Electron dynamics of correlated materials — •Viktor Valmispild[1,2], Vladimir Antropov[3], Evgeny Gorelov[4], Alexander Joura[1], Martin Eckstein[5], and Alexander Lichtenstein[1,2] — [1]Institute of Theoretical Physics, University of Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany — [2]The Hamburg centre for ultrafast imaging, 22761 Hamburg, Germany — [3]Ames Laboratory, Ames, IA 50011, USA — [4]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Germany — [5]Max Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany

The work is focused on theoretical description of electron dynamics in correlated materials. The report consists of two sections:

In the first part we study the single-band Hubbard model on a infnite-dimensional lattice in the presence of a large spatially uniform electric field out of equilibrium. We study the model out of equilibrium using the Keldysh formalism and perturbation theory in the Coulomb interaction U. This work present numerical results for the total energy of the system on an infinite-dimensional hypercubic lattice with nearest-neighbor hopping.

The second part of investigations conducted dynamic magnetic susceptibility simple transition metals Iron, Cobalt and Nickel.

MA 38.8 Wed 11:30 HSZ 403

Ab-initio modelling of spin-fluctuations in classical regime for itinerant ferro- and antiferromagnetics. — •Sergii Khmelevskyi — CMS, IAP, Vienna University of Technology, Vienna, Austria

We present an ab-initio scheme of calculating high-temperature magnetic properties of the itinerant electron systems with strong thermally induced longitudinal fluctuations of the magnetic moments. The scheme is based on the disordered local moment formalism and magnetic force theorem for the calculation of the inter-atomic magnetic exchange interactions. The single-site theory and constrained first-principle calculations has been used for setting the parameters of the mean-field like Heisenberg Hamiltonian with varying amplitude of the spin moment. The transverse (spin-rotation) degrees of freedom, however, have been treated beyond mean-field (Monte-Carlo simulations). We discuss a problem of choosing of a proper statistical measure for the integration over the spin degrees of freedom in classical configurational space. We compare different approaches to the problem for various systems: bcc Fe, fcc Ni, fcc Co, novel itinerant high temperature antiferromagnetic V3Al [1] and "nearly ferromagnetic" FeSi semiconductor. The comparison is done by calculating the magnetic ordering temperatures and high temperature behavior of the susceptibility entirely from first principles. [1] S. Khmelevskyi, Phys. Rev. B 94, 024420 (2016).

MA 38.9 Wed 11:45 HSZ 403

Dzyaloshinskii-Moriya interaction parameters calculated by means of the relativistic KKR Green function method — •Sergiy Mankovsky and Hubert Ebert — Dept. Chemie, Ludwig-Maximilians-Universität München, 81377 München, Germany

A new scheme to calculate the inter-atomic Dzyaloshinskii-Moriya (DM) interaction parameters by means of the relativistic KKR (Korringa-Kohn-Rostoker) Green function method is presented. For this purpose, perturbation theory is used to express the change in energy ΔE caused by a helimagnetic modulation – characterized by a small wave vector $\vec{q}$ – of a magnetically ordered system. The corresponding derivative $\frac{\partial E}{\partial q_\alpha}$ in the limit $q \to 0$ gives access to the various components of the DM vector [1]. Making use of the real space representation of the electronic Green functions as supplied by the KKR formalism an expression for the inter-atomic DM interaction parameters is obtained. The present approach avoids the calculation of the full exchange coupling tensor [2,3] and allows to calculate the components of the DM vector using just one magnetic configuration. Test calculations have been performed for various 3D and 2D systems. The corresponding results are compared with results obtained previously using other schemes suggested in the literature [1,2,3].

[1] F. Freimuth, S. Blügel and Y. Mokrousov, J. Phys.: Condens. Matter **26**, 104202 (2014)

[2] L. Udvardi, L. Szunyogh, K. Palotas, and P. Weinberger, Phys. Rev. B **68**, 104436 (2003)

[3] H. Ebert and S. Mankovsky, Phys. Rev. B **79**, 045209 (2009)

MA 38.10 Wed 12:00 HSZ 403

Bosonic excitations observed at the transition to helical magnetic phases in PrPtAl — •Jean-Philippe Reid[1], D Sokolov[2], C Oneill[3], C Lithgow[3], A Walker[1], M Lizaire[1], S Codsi[1], E Yelland[3], P Wahl[1], and Andrew Huxley[3] — [1]School of Physics and Astronomy, University of St. Andrews, St. Andrews, UK — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [3]School of Physics and CSEC, University of Edinburgh, Edinburgh, UK

Transport and thermodynamic measurements were performed on the rare earth platinum aluminide PrPtAl through the helical magnetic phases, located in a narrowed temperature range between the ferromagnetic and paramagnetic phases. We detected an additional bosonic contribution to the thermal conductivity which can only be related to the helical magnetic phase. This additional bosonic contribution accounts for most of the increase of the density of states observed in the specific heat. It suggests that the emergence of the helical magnetic phases is accompanied by strong bosonic fluctuations which not only induce scattering, but also contribute to the thermal conductivity. Quantum order-by-disorder theory effectively integrates over boson modes and considers fermionic quantum fluctuations. Our findings suggests direct consideration of the boson modes may provide greater insight.

MA 39: X-Ray Imaging, Holography, Ptychography and Tomography

Time: Wednesday 9:30–11:30 Location: MER 02

Invited Talk MA 39.1 Wed 9:30 MER 02

X-ray Microscopy: Imaging the Chemistry Inside — •Christian G. Schroer — Photon Science, DESY, Notkestr. 85, 22607 Hamburg — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

One key strength of hard X-ray microscopy is that it can image the inner structures of an object without destructive sample preparation. Exploiting various X-ray analytical contrasts, such as fluorescence, diffraction, and absorption, the elemental, structural, and chemical information can be obtained from inside a sample, e. g., a chemical reactor. Conventional X-ray microscopy is currently limited by X-ray optics to a few tens of nanometers. One way to overcome this limitation is scanning coherent X-ray diffraction microscopy also known as ptychography [1]. It can be combined with spectroscopy to obtain chemical information on a given element of interest [2]. In combination with tomography, the three-dimensional structure of an object can be reconstructed with unprecedented spatial resolution [3]. Here, an overview is given over multimodal X-ray imaging for materials research at modern synchrotron radiation sources.

[1] J. Rodenburg, H. Faulkner, Appl. Phys. Lett. 85, 4795 (2004); P. Thibault, et al., Science 321, 379 (2008); A. Schropp, et al., Appl. Phys. Lett. 96, 091102 (2010); A. Schropp, et al., Appl. Phys. Lett. 100, 253112 (2012); J. Reinhardt, et al., Ultramicroscopy 173, 52 (2017).

[2] R. Hoppe, et al., Appl. Phys. Lett. 102, 203104 (2013).

[3] M. Dierolf, et al., Nature 467, 436 (2010); M. Holler, et al., Scientific Reports 4, 3857 (2014).

MA 39.2 Wed 10:00 MER 02

Imaging with hard X-rays and Nanometer Resolution using Multilayer Zone Plates — •Jakob Soltau[1], Christian Eberl[2], Tim Salditt[1], Hans-Ulrich Krebs[2], and Markus Osterhoff[1] — [1]Röntgenphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen — [2]Materialphysik, Uni-Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

The resolution of zone plates is determined by their smallest zone width. Multilayer zone plates (MZP) can be fabricated using the process of pulsed laser deposition, which allows zone width of 5 nm and less and therefore enabling imaging of X-rays on a nanometer scale [1]. The central challenge in the development of hard X-ray nano-focusing MZPs is the fulfilling of the Bragg condition across the zone plate. To achieve this the individual zones need to be tilted. Latest experiments using tilted-MZPs at synchrotron sources demonstrated successfully a resolution of a few nanometer in a wide X-ray energy range from 7 keV at DESY/Petra III and for the first time with photon energies above 100 keV at ESRF. A new setup and a motorized stage significantly reduced the set-up and measuring time in scanning X-ray microscopy allowing high resolution imaging of soft- and hard-matter samples in a shorter time. In addition to the experiments, 3D simulations have been performed. The propagation of electromagnetic waves inside and behind the MZP proved the advantage of circular MZPs to achieve very high photon flux densities in a single focal point. The simulations were revealing interaction processes like e.g. dynamical diffraction inside the MZPs. [1] Eberl, C. et al. Appl. Surf. Sc

MA 39.3 Wed 10:15 MER 02

The Fluence-Resolution Relationship in Holographic and Coherent Diffractive Imaging — •Johannes Hagemann and Tim Salditt — Institut für Röntgenphysik, Friedrich-Hund-Platz 1, University Göttingen, 37077 Göttingen

The simple question "Which resolution do I get for the invested photon fluence?" is extremely important for x-ray imaging of radiation sensitive specimen, such as biological cells and tissues. This work [1] presents a numerical study of the fluence-resolution behavior for two coherent lens-less x-ray imaging techniques. To this end we compare in numerical experiments the fluence-resolution relationship of inline near-field holography (NFH) and far-field coherent diffractive imaging (CDI). To achieve this, we carry out the phase reconstruction using iterative phase retrieval algorithms on simulated noisy data. Using the incident photon fluence on the specimen as control parameter we study the achievable resolution for two exemplary phantoms (cell and bitmap). A survey based on maximum likelihood estimation [2] of CDI and NFH showed in principle no difference in the encoded information of the measured data for a given fluence. In the current approach we assess the actual reconstructability of the CDI/NFH data via direct phase retrieval. We use then the Fourier Ring Correlation as measure of reconstruction quality i.e. the achievable resolution. Our results indicate a superior performance of holography compared to CDI, for the same fluence and phase reconstruction procedure. [1] J. Hagemann and T. Salditt, Acta Crystallogr. A, (in review) [2] T. Jahn et al., Acta Crystallogr. A, (2017), 73, 1-11

MA 39.4 Wed 10:30 MER 02

Simulations towards high magnification setups in X-ray Talbot-interferometry — •Andreas Wolf, Veronika Ludwig, Jens Rieger, Max Schuster, Maria Seifert, Georg Pelzer, Thilo Michel, Gisela Anton, and Stefan Funk — ECAP - Erlangen Centre for Astroparticle Physics, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen

Compared with the traditional attenuation contrast, X-ray Talbot-interferometry can yield additional information in terms of the differential phase contrast (DPC) and the dark field contrast (DFC) images.

In this imaging modality, which is primarily pursued in the field of medical diagnostics and soft tissue imaging, the Talbot effect leads to the generation of self images of a grating in the beam path. With respect to the thus created spatial reference pattern and by introducing a second grating, the aforementioned contrast modalities can be retrieved either via a phase-stepping approach or by using Moiré-fringes in a single-shot scheme.

In this contribution, we present simulation studies of Talbot-interferometer-based setups featuring high magnifications towards future applications for imaging at XFEL-beamlines and in the field of laboratory astrophysics where a high magnification of object structures is needed to resolve the generated shocks.

15 min. break

MA 39.5 Wed 11:00 MER 02

X-Ray Phase-Contrast Tomography with Anisotropic Source Conditions — •Malte Vassholz, Leon Merten Lohse, and Tim Salditt — Institute for X-Ray Physics, University of Göttingen, Germany

Hard x-ray tomography offers a unique capability to nondestructively map out the three-dimensional structure of a body or material. A major challenge for high-resolution and/or phase-contrast tomography in the laboratory, is the lack of high-brilliance table-top x-ray sources. By suitable generalization of the tomographic measurement geometry and the reconstruction framework, one can significantly relax the brilliance/coherence condition in one of the two lateral source dimensions [1], opening up new opportunities towards nanoscale resolution with low-brilliance table-top x-ray sources. To this end, the framework of the two-dimensional Radon transform, which is the common basis for most analytical x-ray tomography applications, is replaced by the three-dimensional Radon transform. We show applications for absorption tomography as well as phase-contrast tomography for anisotropic source conditions with aspect ratios larger than two orders of magnitude in the lateral source dimensions.

[1] M. Vassholz, B. Koberstein-Schwarz, A. Ruhlandt, M. Krenkel, and T. Salditt, Phys. Rev. Lett. 116, 088101 (2016).

MA 39.6 Wed 11:15 MER 02

Core-shell-shell nanowires studied by coherent x-ray nanobeam — •Arman Davtyan[1], Vincent Favre-Nicolin[2], Ryan B. Lewis[3], Hanno Küpers[3], Lutz Gelhaar[3], Dominik Kriegner[4], Ali Al-Hassan[1], Otmar Loffeld[1], and Ullrich Pietsch[1] — [1]Faculty of Science and Engineering,University of Siegen,57068 Siegen,Germany — [2]The European Synchrotron,71 Avenue des Martyrs,Grenoble,France — [3]Paul-Drude-Institut für Festkörperelektronik,Hausvogteiplatz 5-7,D-10117 Berlin,Germany — [4]4 Department of Condensed Matter Physics,Charles University, Ke Karlovu 5,121 16 Prague 2,Czech Republic

Core-shell-shell heterostructure nanowires (NWs) with 140nm GaAs core, 10nm In(0.10)Ga(0.90)As inner shell and 30nm GaAs outer shell have been investigated by combining coherent x-ray diffraction imaging (CXDI) and ptychograpy in the Bragg geometry. NWs were grown on a prepatterned substrate. Individual nanowires were measured at the ID01 beamline of the ESRF with coherent x-rays of 9keV energy and 150x200 nm full width half maximum (FWHM). 2D ptychography at GaAs (111) Bragg reflection was applied to investigate the nanowire along the growth axis. Ptychographic reconstruction shows the homogeneous structure of the wire along the growth axis. CXDI was applied to record the 3D reciprocal space maps around the symmetric GaAs (111) reflection at different heights along the NW growth axis.

MA 40: Walter Schottky Prize Award (PV IX)

Time: Wednesday 15:00–15:30 Location: HSZ 04

Prize Talk MA 40.1 Wed 15:00 HSZ 04

Magnon transport in spin textures — •Helmut Schultheiss — Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, 01328 Dresden, Germany — Laureate of the Walter-Schottky-Prize

One of the grand challenges in cutting edge quantum and condensed matter physics is to harness the spin degree of electrons for information technologies. While spintronics, based on charge transport by spin polarized electrons, made its leap in data storage by providing extremely sensitive detectors in magnetic hard-drives, it turned out to be challenging to transport spin information without great losses. With magnonics a visionary concept emerged: Utilize magnons - the excitation quanta of the spin system in magnetically ordered materials - as carriers for information. Magnons are waves of the electrons* spin precessional motion. They propagate without charge transport and its associated Ohmic losses, paving the way for a substantial reduction of energy consumption in devices. In this presentation, I will present our recent highlights on magnon propagation and manipulation in non-collinear spin textures. In particular, I will outline how magnons can be steered in magnetic microstructures by locally generated magnetic fields [1] and how magnetic domain walls serve as magnon nanochannels [2].

[1] K. Vogt, et al., Nature Comms. 5, 3727 (2014).
[2] K. Wagner, et al., Nature Nanotech. 11, 432 (2016).

MA 41: Micromagnetism / Computational Magnetics

Time: Wednesday 15:00–18:00 Location: HSZ 101

MA 41.1 Wed 15:00 HSZ 101

Dynamics of skyrmions in chiral ferromagnets — •Stavros Komineas[1,2] and Nikos Papanicolaou[1] — [1]University of Crete, Heraklion, Greece — [2]RWTH Aachen University, 52056, Aachen, Germany

We give a description of the dynamics of topological and non-topological solitons in ferromagnetic films. We study materials with a Dzyaloshinskii-Moriya interaction and easy-axis anisotropy. Our analysis is based on an important link between topology and dynamics which is established through the construction of unambiguous conservation laws. In particular, we study the motion of a topological skyrmion with skyrmion number Q=1 and a non-topological skyrmionium with Q=0 under the influence of an applied field gradient (which plays the role of a force). The Q=1 skyrmion undergoes Hall motion perpendicular to the direction of the field gradient with a drift velocity proportional to the gradient. In contrast, the non-topological Q=0 skyrmionium is accelerated in the direction of the field gradient, thus exhibiting ordinary Newtonian motion. When the applied field is switched off the Q=1 skyrmion is spontaneously pinned around a fixed guiding center, whereas the Q=0 skyrmionium moves with constant velocity v. We give a numerical calculation of a skyrmionium traveling with any constant velocity v that is smaller than a critical velocity vc.

MA 41.2 Wed 15:15 HSZ 101

Interdependence of the spin and lattice dynamics of CrN in the high temperature paramagnetic phase — •Irina Stockem[1,2] and Björn Alling[1,2] — [1]Department of Physics, Chemistry, and Biology (IFM), Linköping University, Sweden — [2]Max-Planck-Institut für Eisenforschung Düsseldorf, Germany

The combined magnetic and structural phase transition at the Néel temperature spurred interest to use CrN as a model system in the development of first-principles based theoretical modeling schemes of paramagnetism. While antiferromagnetic CrN exhibits an orthorhombic crystal structure at low temperatures, the crystallographic ordering becomes cubic rock salt in the paramagnetic range. It is known that the local magnetic moments of the Cr atoms do not vanish even at high temperature and their varying orientation of the magnetic moments as well as the lattice vibrations should be considered when the paramagnetic phase is simulated.

Up to now, this has been done using a combination of ab-initio molecular dynamics with rapidly changing disordered local moments electronic structure method for paramagnetism (DLM-MD). We go beyond the adiabatic approximation for the time dynamics of the magnetic degree of freedom and combine atomistic spin dynamics with ab initio molecular dynamics. A separate spin dynamics and molecular dynamics study of CrN uncovers similar time scales of the vibrations and the spin decoherence time, clearly motivating our development of the combined ASD-AIMD approach to study interdependency between spin and lattice degrees of freedom.

MA 41.3 Wed 15:30 HSZ 101

Reconfigurable nano-scale spin-wave directional coupler — •Qi Wang[1], Philipp Pirro[1], Roman Verba[2], Andrei Slavin[3], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern 67663, Germany — [2]Institute of Magnetism, Kyiv 03680, Ukraine — [3]Department of Physics, Oakland University, Rochester, MI 48309, USA

Spin-wave wavelengths are orders of magnitude smaller than those of electromagnetic waves of the same frequency, and thus, allow for the design of nano-scaled devices for processing of analog as well as digital data. Crossing structures are a prerequisite for the realization of complex integrated two-dimensional spin-wave circuits. A simple X-type crossing does not satisfy the requirements at the nanometer scale. In this work, we study the coupling of spin waves in parallel- and anti-parallel-magnetized nano-scaled waveguides with a gap using micromagnetic simulations. A corresponding analytic theory is developed. The insulator material yttrium iron garnet (YIG) is studied due to its intrinsically low spin-wave damping. Our results show that a spin wave excited in one waveguide transfers all its energy into the second waveguide after the propagation of a certain distance. This can be utilized to cross two magnonic conduits without interaction, as a power divider, or as a frequencies separator.

This research has been supported by ERC Starting Grant 678309 MagnonCircuit.

MA 41.4 Wed 15:45 HSZ 101

Control of magnetization reversal in ferromagnetic coaxial nanorods: micromagnetic simulations — •Irene Iglesias[1], Thomas Feggeler[1], Benjamin Zingsem[1], and Michael Farle[1,2] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg — [2]Center of Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russian Federation

We present the results of micromagnetic simulations on the magnetization reversal in ferromagnetic coaxial nanorods consisting of different ferromagnetic materials in the inner wire and outer dia- and ferromagnetic tubular shells. To make our simulations compatible with real nanorods (typical length 200 nm and diameter 50 nm) that can be obtained by means of colloidal chemistry three main morphologies of coaxial nanorods have been selected: coaxial cylinders, coaxial ellipsoids and coaxial nanobones. Parameters were chosen such that two state magnetic switching was obtained and the arrangement of magnetic moments during the magnetization reversal was analyzed. The magnetic field was applied along the nanorods axis for all simulations. It is shown that the magnetization dynamics of ferromagnetic coaxial nanorods can be controlled by tuning their thickness, length and composition. The results of our studies may allow the enhanced control of magnetization reversal in coaxial structures, increasing their potential for biological applications and as information carriers in storage devices.

MA 41.5 Wed 16:00 HSZ 101

Calculating GMR in granular Systems using 3D resistor networks — •Daniel Kappe[1,2], Christian Schröder[2], and Andreas

Hütten[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Bielefeld Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Germany

To investigate the impact of particle arrangement on the Giant Magnetoresistance (GMR) effect in granular systems, a resistor network model has been devised to calculate GMR in these systems. Analytical solutions to this problem usually neglect the specific arrangement of particles and instead implement their properties as mean values. This is sufficient for studying large clusters of particles, but might fall short as soon as smaller, organized arrangements are of interest.

Our model uses the geometric arrangement of particles and their micromagnetic state to calculate the system's resistivity. The input is modelled as a three dimensional network of resistors, which is then converted into a set of linear equations. Its solution can be determined inverting the system's matrix.

Combining this approach with micromagnetic simulations, it is possible to calculate the resistivity for arbitrary external magnetic fields, particle arrangements and particle shapes.

15 min. break.

MA 41.6 Wed 16:30 HSZ 101

Shell-ferromagnetism of nano-precipitate in a Ni-Mn-In off-stoichiometric Heusler alloy by ferromagnetic resonance — •Franziska Scheibel[1], Detlef Spoddig[1], Ralf Meckenstock[1], Asli Çakir[2], Michael Farle[1], and Mehmet Acet[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Department of Metallurgical and Materials Engineering, Muğla Sitki Koçman University, 48000 Mugla, Turkey

Previous studies have shown that the off-stoichiometric Ni-Mn-based Heusler alloys decompose into a ferromagnetic (FM) $Ni_{50}Mn_{25}X_{25}$ Heusler alloy and the antiferromagnetic $Ni_{50}Mn_{50}$ alloy during temper-annealing [1]. Annealing of $Ni_{50}Mn_{45.1}In_{4.9}$ in a field of 5 T leads to an alignment of the magnetic moments at the interface of the nano-precipitates along the field direction, leading to a vertical shift of the magnetic hysteresis which is stable up to 9 T and 500 K. The hard magnetic shell can only be reversed in a field of 12 T, which makes this material interesting for permanent magnetic memory application. We studied the coupling mechanism and interface exchange energy by ferromagnetic resonance (FMR). Bidirectional FMR measurements in the range $-1.1 \leq \mu_0 H \leq 1.1$ T at 400 K show a corresponding signal to the decomposed FM phase, indicating a shape anisotropy. FMR studies up to 12 T shows that the FMR of the hard magnetic shell appears at the same resonance field as the FMR of the soft magnetic core but is only present after saturation at 12 T. Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

[1] A. Çakir et al., Sci. Rep. 6 , 28931 (2016)

MA 41.7 Wed 16:45 HSZ 101

High throughput screening for magnetic antiperovskites M_3XY (M = Cr, Mn, Fe, Co, and Ni, and Y = C or N) — Zeying Zhang, •Harish K. Singh, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, Jovanka-Bontschits-Str. 2, 64287 Darmstadt, Germany

Like perovskite materials, compounds with antiperovskite structure show many intriguing physical properties like superconductivity, barocaloric effect, negative thermal expansion etc. In the present work, we investigate the stability of antiperovskite M_3XY (M = Cr, Mn, Fe, Co, and Ni, and Y = C or N) compounds based on extensive first-principles calculations. Assuming crystal structures with $Pm\bar{3}m$ space group, the thermodynamic, mechanical, and dynamical stabilities have been examined by evaluating the formation energy, elastic constants, and phonon spectra. The distance from the convex hull has been evaluated by considering *all* possible decompositions into binary compounds available in the Materials Project database. In order to benchmark our calculations, the stability criteria have been validated on existing antiperovskite materials. Based on the calculations, we predict more than 20 new antiperovskite compounds which satisfy all the above mentioned stability criteria. We hope our work will stimulate more experimental efforts to synthesize and characterize the predicted novel antiperovskite materials.

MA 41.8 Wed 17:00 HSZ 101

Size-induced changes of structural and ferromagnetic properties in $La_{1-x}Sr_{Sr}MnO_3$ nanoparticles — •Cornelia Hintze[1], Dirk Fuchs[1], Michael Merz[1,2], Houari Amari[3], Christian Kübel[2,3], Meng-Jie Huang[1], Annie Powell[3,4], and Hilbert von Löhneysen[1] — [1]Karlsruhe Institut für Technologie, Institut für Festkörperphysik, 76021 Karlsruhe — [2]Karlsruhe Institut für Technologie, Karlsruhe Nano Micro Facility, 76021 Karlsruhe — [3]Karlsruhe Institut für Technologie, Institut für Nanotechnologie, 76021 Karlsruhe — [4]Karlsruhe Institut für Technologie, Institut für Anorganische Chemie, 76021 Karlsruhe

$La_{1-x}Sr_xMnO_3$ nanoparticles (NP) were grown by microemulsion, with Sr concentrations from $x = 0.35$ to 0.50 and diameters between 20 and 40 nm. This technique allows the controlled growth of structurally well-defined NP in a range of sizes using the same preparation conditions. With decreasing particle size, the unit cell volume and the Mn-O bond length increase, while the Mn-O-Mn bond angle decreases. The size-dependent change of structural properties is possibly related to surface effects or disorder. With the decrease of NP size the ferromagnetic ordering temperature T_C decreases by up to 20%. The reduction of T_C can be understood with respect to structural changes: the increase of Mn-O bond length and decrease of Mn-O-Mn bond angle weaken the double-exchange coupling and hence reduce T_C. In addition the intrinsic finite-size effect reduces T_C. The observed size-induced change of magnetic properties may allow for a controlled manipulation of magnetism in $La_{1-x}Sr_xMnO_3$ NP by varying NP size.

MA 41.9 Wed 17:15 HSZ 101

Magnetic characterization of cobalt ferrite nanoparticles in PEG-solution studied by Mössbauer spectroscopy and magnetic AC-susceptometry — •Samira Webers[1], Joachim Landers[1], Soma Salamon[1], Melissa Hermes[2], Annette M. Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute for Physical Chemistry, University of Cologne

Spherical, monodisperse cobalt ferrite nanoparticles dispersed in an aqueous solution display fast Brownian motion. By adding polyethylene glycol (PEG) the viscosity of the mixture increases and the particle motion is slowed by the PEG chains. We investigate the influence of different PEG chain lengths and various concentrations resulting in similar macroscopic properties by magnetic characterization of the particle motion via Mössbauer spectroscopy and AC-susceptometry (ACS). The main aspect is to study the particle-matrix interaction in macroscopic similar mixtures which differ in their microscopic composition. Since the particles are in the size of the structural units of the matrix, the relative length scale of the magnetic particles compared to the size of the structural units of the polymer gets relevant and is expected to influence the particle mobility. Further structural characterization of the particles regarding to the particle size and spinel structure are performed by low temperature in-field Mössbauer spectroscopy. To crosscheck the Mössbauer results, the Brownian rotation frequency of the particles is studied by ACS. This work is supported by the DFG-Priority Programme SPP1681.

MA 41.10 Wed 17:30 HSZ 101

Inverse magnetostrictive stress sensors based on CoFeB/MgO/CoFeB tunnel junctions — •Niklas Dohmeier[1], Günter Reiss[1], Karsten Rott[1], Ali Tavassolizadeh[2], and Dirk Meyners[2] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute for Materials Science, Christian-Albrechts-Universität zu Kiel

We investigate double-pinned CoFeB/MgO/CoFeB tunnel junctions as sensors for mechanical stress.

Applying stress on a magnetic material induces an anisotropy. Depending on the material and direction of the stress, the anisotropy can be parallel or perpendicular to the stress direction. This effect can be utilized in TMR stacks to detect mechanical stress via changes in the tunnel resistance.

A standard TMR stack with a pinned and a free magnetic layer needs a magnetic bias field to set the optimum working condition. We are aiming for a replacement of the external bias field.

TMR stacks have been realized with MnIr-based pinning of both electrodes. By choosing different MnIr thicknesses, different blocking temperatures were accomplished. Through a series of field cooling processes with increasing temperatures the optimum temperature was found for crossed ground state magnetizations of the electrodes.

On these systems TMR measurements and bending experiments have been performed in order to show the performance of non-collinear pinned TMR stacks as stress sensors with the possibility of differentiating tensile and compressive stress.

MA 41.11 Wed 17:45 HSZ 101

Magnetoelastic modeling of ΔE-effect magnetic field sensors for sub nT — •Benjamin Spetzler[1], Sebastian Zabel[1], Christine Kirchhof[2], Eckhard Quandt[2], and Franz Faupel[1] — [1]Institute for Materials Science, Chair for Multicomponent Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel, Germany — [2]Institute for Materials Science Chair for Inorganic Functional Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel, Germany

Stimulated by our new approach of a fully integrable ΔE-effect magnetic field sensor [Gojdka et al., APL 99 (2011) 223502, Nature 480 (2011) 155], we present a comprehensive description of the ΔE-effect in magnetostrictive thin films and their application for magnetic field sensors. The ΔE-effect describes the nonlinearity of stress-strain behavior in magnetic materials. It originates from magnetoelastic coupling and results in a change of elastic modulus upon application of a magnetic field. This is modeled using an extended Stoner-Wohlfarth approach including anisotropy distributions and thin film geometry. The model is then expanded to correctly describe the properties of a MEMS cantilever resonance shift with magnetic field and stress. Such high Q cantilevers have been studied intensely for the application as magnetic field sensors. To operate the sensor, it is externally excited using an additional piezoelectric layer of AlN. The impedance change of this magnetically detuned electromechanical resonator is used for high sensitivity sensors able to detect magnetic fields well below 1 nT.

MA 42: Transport: Topological Semimetals 2 (jointly with DS, MA, HL, O)

Time: Wednesday 15:00–17:45 Location: HSZ 204

MA 42.1 Wed 15:00 HSZ 204

Topological properties of magnetic semi-metals with non-symmorphic symmetries — •Andreas P. Schnyder — Max Planck Institute of Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart

Topological semi-metals exhibit band crossings near the Fermi energy, which are protected by the non-trivial topological character of the wave functions. In many cases, these topological band degeneracies give rise to exotic surface states and unusual magneto-transport properties. In this talk, I will discuss this physics in the context of *magnetic* semimetals with non-symmorphic symmetries. In particular, I will show that non-symmorphic symmetries of cubic magnetic space groups lead to protected four-fold degenerate Dirac points and Dirac lines. As a concrete example, I will examine the topological properties of the antiferromagnet $CuBi_2O_4$ in terms of a low-energy tight-binding model, derived from ab-initio DFT calculations. I will discuss the monopole charges and the associated surface states of this system.

MA 42.2 Wed 15:15 HSZ 204

Density wave instabilities and surface state evolution in interacting Weyl semimetals — Manuel Laubach[1], Chrstian Platt[2], Ronny Thomale[3], Titus Neupert[4], and •Stephan Rachel[1] — [1]TU Dresden — [2]Stanford University — [3]University of Würzburg — [4]University of Zürich

We investigate the interplay of many-body and band structure effects of interacting Weyl semimetals (WSM). Attractive and repulsive Hubbard interactions are studied within a model for a time-reversal-breaking WSM with tetragonal symmetry, where we can approach the limit of weakly coupled planes and coupled chains by varying the hopping amplitudes. Using a slab geometry, we employ the variational cluster approach to describe the evolution of WSM Fermi arc surface states as a function of interaction strength. We find spin and charge density wave instabilities which can gap out Weyl nodes. We identify scenarios where the bulk Weyl nodes are gapped while the Fermi arcs still persist, hence realizing a quantum anomalous Hall state.

MA 42.3 Wed 15:30 HSZ 204

Experimental observation of type-II Weyl states in $TaIrTe_4$ — •Erik Haubold[1], Klaus Koepernik[1], Dmitriy Efremov[1], Seunghyun Khim[2], Alexander Fedorov[1,3], Yevhen Kushnirenko[1], Jeroen van den Brink[1,4], Sabine Wurmehl[1,4], Bernd Büchner[1,4], Timur Kim[5], Moritz Hoesch[5], Kazuki Sumida[6], Kazuaki Taguchi[6], Tomoki Yoshikawa[6], Akio Kimura[6], Taichi Okuda[7], and Sergey Borisenko[1] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]MPI CPfS, 01187 Dresden, Germany — [3]II. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany — [4]Department of Physics, TU Dresden, 01062 Dresden, Germany — [5]Diamond Light Source, Didcot OX11 0DE, United Kingdom — [6]Graduate School of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan — [7]Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima 739-0046, Japan

Weyl semimetals have raised a lot of interest lately due to their interesting exotic surface states. $TaIrTe_4$, belonging to the recently introduced class of type-II Weyl semimetals, hosts 4 Weyl points. These are well separated in the Brillouin zone and connected by rather long and parralel Fermi Arcs, making the material especially interesting for further research and future applications. In this work we find direct correspondence between theoretical predictions and ARPES results for both bulk and the surface states. Remarkably, these surface states are spin polarized, highlighting the potential for novel applications.

MA 42.4 Wed 15:45 HSZ 204

Magneto-optical infrared studies of the Weyl semimetals TaAs, TaP and NbP — D. Neubauer[1], R. Kemmler[1], W. Li[1], R. Hübner[2], A. Löhle[1], M. Schilling[1], M. Schmidt[3], C. Shekhar[3], C. Felser[3], M. Dressel[1], and •A. V. Pronin[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]FMQ, Universität Stuttgart, Germany — [3]MPI CPfS, Dresden, Germany

We have investigated the infrared response of TaAs, TaP, and NbP in zero magnetic field and in fields of up to 30 T. Additionally, magneto-transport measurements have been conducted on the same samples. In all compounds, we can reliably trace the transitions between different Landau levels. The transition frequencies demonstrate a square-root field dependence, typical for the linearly dispersed bands. In TaP, we can also see a sizeable shifting of the plasma edge in magnetic field and an interplay between this plasma-edge shift and the Landau-level transitions. We compare the optical spectra of the three compounds, describe the spectra by the recent models for the (magneto)-optical response of Weyl semimetals, and extract such parameters as the Fermi velocities of the carriers in the Weyl bands and the positions of the Fermi levels relative to the Weyl points.

MA 42.5 Wed 16:00 HSZ 204

Emergent Weyl fermion bulk excitations in TaP evidenced from ^{181}Ta quadrupole resonance — H. Yasuoka[1,2], T. Kubo[1,3], Y. Kishimoto[1,3], D. Kasinathan[1], M. Schmidt[1], B. Yan[1], Y. Zhang[4], H. Tou[3], C. Felser[1], A.P. Mackenzie[1,5], and •M. Baenitz[1] — [1]MPI for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan — [3]Department of Physics, Graduate school of Science, Kobe University, Kobe, Japan — [4]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [5]SUPA, School of Physics & Astronomy, University of St. Andrews, UK

The monophosphite TaP has a non centrosymmetric structure and sizable spin orbit coupling and belongs the class of Weyl semimetals. A crossing of lineare dispersive ($E \propto k$) topologically protected polarized bands in a single point in reciprocal space defines the Weyl node where the fermion mass vanishes theoretically and a giant orbital hyperfine coupling is expected [1]. ^{181}Ta quadrupole resonance (NQR) resolves three NQR lines associated to the split level transitions for I=7/2 Ta. The spin lattice relaxation was measured for the $\pm 5/2 \leftrightarrow \pm 3/2$ transition. Above 30 K, a pronounced $(1/T_1T) \propto T^2$ is found. We attributed this to the magnetic excitations of Weyl fermions ($N(E) \propto E^2$) with temperature dependent orbital hyperfine coupling in agreement with the prediction from theory [1].

[1] Z. Okvatovity et al., arXiv:1609.3370v1

15 min. break.

MA 42.6 Wed 16:30 HSZ 204

Magnetic Properties of Dirac Fermions in a Family of Anti-perovskites — •Moritz Mandes Hirschmann and Andreas

Philipp Schnyder — Max Planck Institute for Solid State Research, Stuttgart, Germany

We study the magnetic properties of the anti-perovskite materials A_3EO, where A denotes an alkaline earth metal, while E stands for Pb or Sn. The low-energy electronic properties of this family of anti-perovskites is described by three-dimensional Dirac fermions, which are gapped out by spin-orbit coupling [1-3]. We discuss the magnetic response of this Dirac electron system, considering both orbital and spin Zeeman effects. Interestingly, a strong Zeeman field splits the gapped Dirac cones into ungapped Weyl points, which are protected by a quantized Chern number. The compound Eu_3PbO breaks in its ferromagnetic phase intrinsically the time-reversal symmetry by exhibiting a magnetization that corresponds to a large Zeeman splitting at the Europium atoms. Again we observe Weyl points in the band structure. Using a tight-binding description we calculate these Chern numbers and demonstrate that the Weyl points are connected by Fermi arcs in the surface Brillouin zone. Furthermore, we determine the Landau level structure of the gapped Dirac electrons.

[1] T. H. Hsieh, J. Liu, and L. Fu. *Phys. Rev. B*, 90:081112, Aug 2014
[2] J. Nuss, C. Mühle, K. Hayama, V. Abdolazimi, and H. Takagi. *Acta Crystallographica Section B*, 71(3):300-312, Jun 2015.
[3] D. Samal, H. Nakamura, and H. Takagi. *APL Mater.*, 4(7), 2016.

MA 42.7 Wed 16:45 HSZ 204

Emergent Weyl points from Floquet Weyl semimetals in the resonant limit — •Leda Bucciantini[1], Stithadi Roy[1], Sota Kitamura[2], and Takashi Oka[1] — [1]Max Planck Institute for Physics of Complex Systems, Germany — [2]Tokyo University, Japan

We investigate the formation of Weyl points from a Dirac semimetal after shining it with circularly polarized light, focusing on the resonant frequency limit. Within a Floquet formalism, we describe the phase diagram as a function of the intensity and frequency of the laser. A couple of Weyl points split both from the original Dirac point and from the Floquet side bands. Increasing the value of the laser intensity, the Weyl points emerging from the original Dirac point and the side band merge, annihilate and then gap out. We also compute the monopole charge for each of the emergent Weyl points.

MA 42.8 Wed 17:00 HSZ 204

Self-forming superconducting microstructures from Weyl semi-metals — •Maja D. Bachmann[1], Nityan Nair[3], Felix Flicker[3], Roni Ilan[3], Nirmal J. Ghimire[2], Eric D. Bauer[2], Filip Ronning[2], James G. Analytis[3], and Philip J.W. Moll[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Los Alamos National Laboratory, Los Alamos, NM, USA — [3]Department of Physics, University of California Berkeley, CA, USA

The non-trivial topology of the bulk bands in topological semi-metals protects new electronic states at the surface, such as the famous Fermi arc states. If a superconducting gap is induced in these materials, exotic electronic states are expected to appear at the interface such as zero-energy Majorana modes. These novel states provide insights into the topological aspects of electronic matter and are of interest for quantum coherent applications. Here we will present a new route to reliably fabricating superconducting microstructures from the intrinsically non-superconducting Weyl semi-metals NbAs and TaAs under ion irradiation. The large difference in the surface binding energy of Nb/Ta and As leads to a natural enrichment of Nb/Ta at the surface during ion milling, forming a superconducting surface layer (Tc~3.5K). Being formed from the target crystal itself, the ideal contact between the superconductor and the bulk enables an effective gapping of the nodes due to the proximity effect. Simple low energy ion irradiation may thus serve as a powerful tool to fabricate topological quantum devices from mono-arsenides, even on an industrial scale.

MA 42.9 Wed 17:15 HSZ 204

Angle-dependent magnetoresistance in Weyl semimetals with long-range disorder — •Jan Behrends[1] and Jens H Bardarson[1,2] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Department of Theoretical Physics, KTH Royal Institute of Technology, Stockholm, SE-106 91 Sweden

The chiral anomaly is one of the most intriguing features of Weyl semimetals. It states that left- and right-handed fermions are not conserved individually, while their sum is. One of its experimental consequences is the negative magnetoresistance predicted in Weyl semimetals. Recent experiments show strong indications for such an anomalous conductivity response, while some outstanding issues remain. Most prominently, the anomalous response is much more sharply peaked for parallel magnetic and electric fields than expected from simple theoretical considerations. Here, we investigate scattering in Weyl semimetals in presence of magnetic fields for a correlated disorder potential. We find a decrease of the internode relaxation time when the magnetic field is tilted away from the separation of the Weyl nodes. Since the internode relaxation time is proportional to the anomaly-related conductivity, this feature may explain the narrow current plume seen experimentally.

MA 42.10 Wed 17:30 HSZ 204

Surface states in holographic Weyl semimetals — •Markus Heinrich, Amadeo Jimenez-Alba, Sebastian Möckel, and Martin Ammon — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena

Weyl semimetals (WSMs) are a class of gapless topological materials with low-energy excitations behaving as Weyl fermions. Their most prominent feature are topologically protected surface states, so-called Fermi arcs, which were recently tied to an effective axial magnetic field arising at a surface due to lattice deformations. As in the chiral magnetic effect, this field gives rise to an anomalous current at finite chemical potential which is localised at the surface. We performed its subtle computation in the strong coupling limit by using a holographic model. We found a non-trivial unversality of the current, allowing us to interpret it in a simple Fermi arc-like picture. In the end, I will discuss the limits of this universality.

MA 43: Topological Insulators I (jointly with DS, HL, O, TT)

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

MA 43.1 Wed 15:00 HSZ 401

Mn-doped topological insulators Bi_2Te_3 and Bi_2Se_3: an ab initio study of magnetism and transport properties — •Karel Carva[1], Pavel Baláž[1], Jakub Šebesta[1], Josef Kudrnovský[2], František Máca[2], and Václav Drchal[2] — [1]Charles University, DCMP, Ke Karlovu 5, CZ-12116 Prague, Czech Republic — [2]Institute of Physics, ASCR,Na Slovance 2, CZ-18221 Prague, Czech Republic

For the interpretation of experiments studying the Bi_2Te_3 and Bi_2Se_3 family of topological insulators it is necessary to include the native defects into the picture. Using similar methods one can study also the magnetic doping, which has attracted a lot of interest recently [1]. We calculate on an ab initio level the electronic structure of Bi_2Te_3 and Bi_2Se_3 doped by Mn at different possible positions and also in the presence of native antisites and vacancies. This provides for the first time a comprehensive map of possible behavior affecting strongly the bulk resistivity, carrier concentration and magnetism. It allows us to tune these properties, and also help to uncover the location of Mn atoms, since the substitutional or interstitial Mn placement exhibits strikingly different properties. Calculations indicate that the presence of interstitials may help to understand experimental observations[2].

Exchange interactions between Mn magnetic moments in bulk Mn-doped Bi_2Te_3 / Bi_2Se_3 have been calculated using ab initio methods. These results allow us to study the Curie temperatures by means of atomistic Monte Carlo simulations.

[1] Y. S. Hor et al., Phys. Rev. B 81, 195203 (2010)
[2] K. Carva et al., Phys. Rev. B 93, 214409 (2016)

MA 43.2 Wed 15:15 HSZ 401

Unraveling the Spin Structure of Unoccupied States in Bi_2Se_3 — •Christian Langenkämper[1], Anna Zumbülte[1], Jürgen Braun[2], Tobias Förster[3], Anke B. Schmidt[1], Jianli Mi[4], Bo Iversen[4], Philip Hofmann[5], Jan Minár[2,6], Hubert Ebert[2], Peter Krüger[3], Michael Rohlfing[3], and Markus Donath[1] —

[1]Physikalisches Institut, WWU Münster, Germany — [2]Department of Chemistry, LMU München, Germany — [3]Institut für Festkörpertheorie, WWU Münster, Germany — [4]Center for Materials Crystallography, Department of Chemistry, Aarhus University, Denmark — [5]Department of Physics and Astronnomy, Interdisciplinary Nanoscience Center, Aarhus University, Denmark — [6]New Technologies Research Centre, University of West Bohemia Pilzen, Czech Republic

The control of spin currents in topological insulators using optical transitions opens new perspectives in (opto-)spintronics. To understand these processes involving topological surface states, a profound knowledge about the dispersion and the spin polarization of both the occupied and the unoccupied electronic states is crucial. We present a joint experimental and theoretical study on the unoccupied electronic states of Bi_2Se_3. We discuss spin- and angle-resolved inverse photoemission results in comparison with calculations for both the intrinsic band structure and, within the one-step model of (inverse) photoemission, the expected spectral intensities. This allows us to unravel the intrinsic spin texture of the unoccupied bands at the surface of Bi_2Se_3.

MA 43.3 Wed 15:30 HSZ 401

Enhanced Mobility of Spin-Helical Dirac Fermions in Disordered 3D Topological Insulators — Joseph Dufouleur[1], Louis Veyrat[1], Bastien Dassonneville[1], Christian Nowka[1], Silke Hampel[1], Pavel Leksin[1], Barbara Eichler[1], Oliver G. Schmidt[1], Bernd Büchner[1], and •Romain Giraud[1,2] — [1]IFW, Dresden, Germany — [2]INAC-SPINTEC, Grenoble, France

We reveal the enhanced transport length of 2D spin-helical Dirac fermions in highly-disordered 3D topological insulators, due to anisotropic scattering, by electrical transport measurements of Bi_2Se_3 nanostructures [1]. By comparing the quantum mobility, related to the electronic mean-free path, to the mobility obtained from transconductance measurements, related to the transport length (backscattering), we evidence the long-range nature of the scattering potential for surface Dirac fermions and some limitation due to a residual bulk/surface coupling. In wide nanostructures, it is shown that the long phase coherence length results from the enhanced diffusion constant, in very good agreement with results obtained from previous studies of the weak anti-localization [2]. Our work suggests that the spin-flip length ($l_{\mathrm{sf}} \approx l_{\mathrm{tr}}$) could reach the micron size in materials with a reduced bulk doping, which reveals the true potential for building functionalized spintronic and ballistic electronic devices out of disordered 3D topological insulators.

[1] J. Dufouleur et al., Nano Lett. 16, 6733 (2016)
[2] Z. Li et al., Phys. Rev. B 91, 041401 (2015)

MA 43.4 Wed 15:45 HSZ 401

Spin-dependent very-low-energy electron diffraction at Bi_2Se_3 — •Andre Reimann[1], Christian Langenkämper[1], Anna Blob[1], Jürgen Braun[2], and Markus Donath[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany — [2]Department Chemie, Ludwig-Maximilians-Universität München, Germany

The topological insulator Bi_2Se_3 exhibits prominent spin effects in both the occupied and unoccupied electronic bandstructure due to strong spin-orbit coupling. This promises large effects also for spin-dependent electron reflection.

We present a combined experimental and theoretical study of the spin-dependent electron reflection of Bi_2Se_3 along the $\overline{\Gamma}\,\overline{\mathrm{K}}$ and the $\overline{\Gamma}\,\overline{\mathrm{M}}$ direction. Experimentally we performed spin-dependent very-low-energy electron diffraction (VLEED) experiments over a wide range of energies and angles of incidence. Theoretically we used ab-initio calculations by means of the SPKKR layer code.

For both directions, we derived maps for the reflectivity and the Sherman function. We found high spin asymmetries up to 37%, which are caused by the large spin-orbit coupling of Bi_2Se_3. These features show a strong energy and angle dependence. Futhermore, we identified the VLEED finestructures, which contain information about the surface barrier.

MA 43.5 Wed 16:00 HSZ 401

Theoretical investigations of magnetically doped topological insulators — •Jan Minar[1,2], Jürgen Braun[1], Hubert Ebert[1], Jaime Sanchez-Barriga[3], Oliver Rader[3], Jan Honolka[4], and Andreas Ney[5] — [1]LMU München, Germany — [2]University of West Bohemia, Plzen, Czech Rep. — [3]Helmholz Zentrum, Berlin — [4]ASCR, Institute of Physics, Prague — [5]Johannes Kepler University Linz, Austria

Band gap opening of topological surface states due to magnetic doping is the subject of a long standing and ongoing discussion. However, in spite of the progress made during the last years in this field there are still phenomena that are poorly understood and many open issues to be addressed. In several cases, like for example Mn doped Bi_2Se_3 band gap opening does not seem to be of magnetic origin. We will present several examples for detailed theoretical studies on various bulk as well as surface doped topological insulators performed by means of the SPR-KKR band structure method. Our results will be discussed in direct comparison with corresponding ARPES [1], XAS and XMCD [2,3] experimental data.

[1] J. Sanchez-Barriga et al., Nat. Communications, 7, 10559 (2016)
[2] A. Ney et al., in preparation
[3] J. Honolka et al., PhysRevB 94, 161114 (2016)

15 min. break.

MA 43.6 Wed 16:30 HSZ 401

Lifetime and surface to bulk scattering of the topological surface state in 3D topological Insulators — •Philipp Rüssmann, Phivos Mavropoulos, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Doping of topological insulators, such as Bi_2Se_3 or Bi_2Te_3, may result in a shift of the Fermi level to a position where the Topological Surface States (TSS) and the bulk states coexist. Then, the TSS lifetime τ_s due to impurity scattering is decomposed in surface-to-surface and surface-to-bulk contributions with scattering rates τ_{ss}^{-1} and τ_{sb}^{-1}, respectively, where $\tau_s^{-1} = \tau_{ss}^{-1} + \tau_{sb}^{-1}$. We investigate this decomposition in Bi_2Se_3 and Bi_2Te_3 by means of density-functional calculations.

In a detailed analysis we find that conduction and valence band play a different role in the surface to bulk state scattering. Especially for the important case of n-doping, the conduction band contribution is very small compared to the surface-state contribution. As a consequence, the surface electrons remain topologically protected in spite of coexisting bulk bands.

For the calculation of electronic structure and scattering properties we employed the full potential relativistic Korringa-Kohn-Rostoker Green-function method. We acknowledge financial support from the DFG (SPP-1666), from the VITI project of the Helmholtz Association and computational support from the JARA-HPC Centre at the RWTH Aachen University.

MA 43.7 Wed 16:45 HSZ 401

Surfaces and interfaces of topological insulators from relativistic many-body calculations. — •Irene Aguilera, Christoph Friedrich, and Stefan Blügel — Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany.

We present a description of surfaces of topological insulators (TIs) as well as interfaces between different TIs and between TIs and trivial materials. We focus on materials of the Bi_2Se_3 family. We use the all-electron FLAPW formalism and the relativistic many-body *GW* method [1]. Including many-body effects in the calculation and incorporating the spin-orbit coupling into the self-energy are critical to obtain reliable results for these TIs [1-5]. For the description of surface and interface states, we use a basis of Wannier functions to construct the slabs and heterostructures Hamiltonians. This approach allows us to study very large systems with a high accuracy. We discuss the differences between surface and interface states and the interaction ("crosstalk") between energetically non-degenerate Dirac cones at the interface and surfaces of the heterostructure.

[1] Aguilera *et al.*, Phys. Rev. B **88**, 165136 (2013). [2] Aguilera *et al.*, Phys. Rev. B **91**, 125129 (2015). [3] Aguilera *et al.*, Phys. Rev. B **88**, 045206 (2013). [4] Nechaev *et al.*, Phys. Rev. B **87**, 121111(R) (2013). [5] Michiardi *et al.*, Phys. Rev. B **90**, 075105 (2014).

Financial support from the Virtual Institute for Topological Insulators of the Helmholtz Association.

Correspondence: i.aguilera@fz-juelich.de

MA 43.8 Wed 17:00 HSZ 401

Topological thin films of Bi and InBi coexisting on InAs(111) — •L Nicolai[1,2,7], K Hricovini[1,2], J-M Mariot[1,3], M C Richter[1,2], O Heckmann[1,2], U Djukic[1], T Balasubramanian[4], M Leandersson[4], J Sadowski[4], J Denlinger[5], I Vobornik[6], J

Braun[7], H Ebert[7], and J Minar[7,8] — [1]LPMS, UCP, Cergy, France — [2]DSM-IRAMIS, Spec, Cea-Saclay, France — [3]LCP-MR, UPMC Univ. Paris 06/CNRS, France — [4]MAX-lab, Lund Univ., Sweden — [5]ALS, Berkeley, USA — [6]EST, Trieste, Italy — [7]LMU Munich, Germany — [8]Univ. of West Bohemia, Plzeň, Czech Rep.

The Bi(111) surface is a prototype system that shows Rashba-split surface states. Theoretical studies [1] predicted non-trivial topological surface states appearing on a single bi-layer of Bi(111) and a more complex behavior was suggested for a variable film thickness as a function of the layer thickness [2]. This clearly indicates that the electronic properties of thin films of this material are quite complex and far from being fully understood. Here we present combined theoretical and ARPES studies on the electronic structure of Bi(111) films grown on InAs(111). Bi grows epitaxially on this substrate and a monocrystal of very high quality is obtained after depositing several monolayers. ARPES experiments on the samples prepared show several new electronic states not reported before. The one-step model of photoemission as implemented in the SPR-KKR package [3] allows us to identify pristine Bi bulk states coexisting with InBi surface states. [1] Wada et *al.*, Phys. Rev. B 83,121310 (2011) [2] Liu et *al.*, Phys. Rev. Lett. 107, 136805 (2011) [3] Braun, Rep. Prog. Phys. 59, 1267-1338 (1996)

MA 43.9 Wed 17:15 HSZ 401

Instability of the topologically protected surface state in Bi_2Se_3 upon deposition of gold — •Andrey Polyakov[1], Holger L. Meyerheim[1], Christian Tusche[2], Daryl E. Crozier[3], and Arthur Ernst[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany, Germany — [3]Department of Physics, Simon Fraser University Burnaby, BC Canada, V5A 1S6

We present an experimental and theoretical analysis of the stability of the Topological surface state (TSS) in Bi_2Se_3 upon sub-monolayer deposition of Au. Extended x-ray absorption fine structure experiments provide clear evidence that Au -when deposited on the (0001) surface kept at 160 K- substitutes Bi atoms within the first quintuple layer. This goes in parallel with the dramatic weakening of the spectral density of the TSS as observed by angular resolved photoemission. In accordance with first-principles calculations, Au in Bi substitutional sites within the first QL creates a d-type resonant state near E_F, which hybridizes with the TI bands and substantially modifies its surface electronic structure. According to the model of Black-Schaffer et al. [1] a bulk-surface interaction is a prerequisite for the gap opening, since the TSS is not protected by scattering processes involving bulk three-dimensional states. References: [1] A. M. Black-Schaffer and A. V. Balatsky, Phys. Rev. B 86, 115433 (2012). Acknowledgements: Work supported by SPP 1666. Work at the APS is supported by the U.S. DOE under Contract No. DE-AC02-06CH11357.

MA 43.10 Wed 17:30 HSZ 401

Magnetic exchange on the surface of topological insulators — •Alessandro Barla[1], Sanjoy K. Mahatha[1], Paolo Sessi[2], Kai Fauth[2], Thomas Bathon[2], Matthias Bode[2], Miguel Angel Valbuena[3], Sylvie Godey[3], Aitor Mugarza[3], Pierluigi Gargiani[4], Philipp Rüssmann[5], Phivos Mavropoulos[5], Gustav Bihlmayer[5], Stefan Blügel[5], and Carlo Carbone[1] — [1]Istituto di Struttura della Materia, CNR, I-34149 Trieste, Italy — [2]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, D-97074 Würzburg, Germany — [3]Catalan Institute of Nanoscience and Nanotechnology (ICN2), E-08193 Cerdanyola del Vallès, Spain — [4]ALBA Synchrotron Light Source, E-08290 Cerdanyola del Vallès, Spain — [5]PGI-1 and IAS-1, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Three-dimensional topological insulators have conducting surface states in the bulk band gap, protected by time-reversal symmetry, which locks spin with momentum. It was shown, however, that surface magnetic doping can break time-reversal symmetry and induces backscattering of Dirac states [1]. We present the results of our investigations of the magnetic properties of individual atoms of 3d transition metals (Mn, Fe, Co) deposited on the surface of the topological insulator Bi_2Te_3. All studied adatoms present an out-of-plane magnetic anisotropy associated with sizeable orbital moments and we find evidence of surface-mediated magnetic exchange interactions which are of opposite sign for Mn and Co.

[1] P. Sessi et al., Nat. Commun. 5, 5349 (2014).

15 min. break.

MA 44: PhD Symposium Quantum Magnets (contributed talks)

Time: Wednesday 15:00–17:30 Location: HSZ 403

MA 44.1 Wed 15:00 HSZ 403

Evolution of antiferromagnetic domains in the all-in-all-out ordered pyrochlore $Nd_2Zr_2O_7$ — •L. Opherden[1,2], J. Hornung[1,2], T. Herrmannsdörfer[1], J. Xu[3,4], A. T. M. N. Islam[3], B. Lake[3,4], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, Germany — [3]Abteilung Quantenphänomene in neuen Materialien, HZB, Berlin, Germany — [4]Institut für Festkörperphysik, TU Berlin, Germany

We report the observation of magnetic domains in an exotic, antiferromagnetically ordered all-in-all-out state of $Nd_2Zr_2O_7$, induced by spin canting. Two different spin arrangements fulfill this configuration of Ising-like spins. This leads to the occurrence of magnetic domains. While the two all-in-all-out spin arrangements occur equiprobable in zero field, the application of a magnetic field along the [111] direction allows for a change of their domain structure. We have investigated $Nd_2Zr_2O_7$ by means of static magnetization and dynamic susceptibility. The ground state occurs below 0.31 K and is stable for external magnetic fields up to 0.14 T. The magnetic domains are observed through a hysteresis of the susceptibility $\chi_{\rm ac}(H)$. No hysteresis occurs in case the external magnetic field is applied along [100].

MA 44.2 Wed 15:15 HSZ 403

Quasi-toroidal poling of a nanomagnetic lattice — •Jannis Lehmann[1], Claire Donnelly[1,2], Peter Derlet[2], Laura Heyderman[1,2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Paul Scherrer Institute, Villigen PSI, Switzerland

Two-dimensional dipolar coupled magnetic nanostructures can be seen as model spin systems to investigate phenomena such as spontaneous order or magnetic frustration. It is thus possible to model specific types of ferroic order artificially by implementing design elements at the mesoscale. In a suitably engineered unit cell it is possible to achieve uniform spin-ordering in the form of magnetic whirls defining a net toroidal moment. Considering the lattice as a whole, the system can then form energetically degenerate toroidal domains in its ground state with opposite chirality. Our unit cell consists of four lithographically patterned sub-micrometer permalloy bars that are arranged on a silicon substrate forming the edges of a square. We present a strongly coupled nanomagnetic lattice that forms toroidal domains in its as-grown state. A saturated magnetized non-toroidal state can then be switched to a toroidal state by using the stray field of a magnetic tip in a scanning probe microscope. We interpret the poling procedure in terms of application of an effective toroidal field and present the possibility to write domains of defined handedness. As a first quasi-toroidal poling process in an artificial lattice, this work is an important step towards accessing the physics of ferrotoroidicity as a new type of ferroic order at mesoscopic length scales.

MA 44.3 Wed 15:30 HSZ 403

Minimal model for the frustrated spin ladder system $BiCu_2PO_6$ — •Leanna Splinter[1], Nils Alexander Drescher[2], Holger Krull[3], and Götz Silvester Uhrig[4] — [1]tu Dortmund — [2]tu Dortmund — [3]tu Dortmund — [4]tu Dortmund

The microscopic model of the compound $BiCu_2PO_6$ contains tubelike structures, which can be described by coupled frustrated spin ladders with a finite gap. Inelastic neutron scattering experiments showed that the triplon excitation modes are split and not three-fold degenerate, as would be expected for spin isotropy. Because of the large atomic number of the bismuth ions (Z=83) the spin-orbit-coupling has a non-negligible effect by the Dzyaloshinskii-Moriya interaction on the dispersion. Using a deepCUT approach for the isotropic model and including the anisotropic interactions on a mean-field level we are able to describe the low-energy part of the dispersions by Dzyaloshinskii-Moriya interactions of about 30 % [1]. Additionally, we can reproduce the magnetic field dependence. Currently, we are extending our model from the one-particle level to including quasi-particle decay, which is induced by the anisotropic interactions. The hydridization between one- and two-triplon states is claimed to explain the different bending behaviour of the individual triplon dispersions [2].

[1] L. Splinter *et al.*, Phys. Rev. B 94, 155115 (2016).
[2] K. W. Plumb *et al.*, Nat. Phys. 12, 224 (2015).

MA 44.4 Wed 15:45 HSZ 403

Magnetic correlations in artificial xy spin systems — •Naëmi Leo[1], Oles Sendetskyi[1], Dominik Schildknecht[1], Peter Derlet[1], Stefan Holenstein[1], Hubertus Luetkens[1], Stephen Lee[2], and Laura J. Heyderman[1] — [1]Paul Scherrer Institute, Villigen, Switzerland — [2]St. Andrews University, St. Andrews, Scotland

The coupling of continuous spin degrees of freedom on two-dimensional lattices can give rise to interesting phenomena such as the topological Kosterlitz-Thouless transition. A model system to study the influence of external parameters on the magnetic order can be emulated by controlled arrangements of nanomagnets coupled via dipolar interactions. Using electron beam lithography periodic arrangements of circular dots with diameters in the order of a few tens of nanometers can be patterned. Due to the circular shape of the magnetic dots, the resulting macrospin resembles a freely-rotating in-plane xy moment.

Here, we investigate the thermal behaviour and onset of magnetic correlations of fluctuating, interacting xy moments on a square lattice using low-energy muon spin relaxation (muSR), which is a highly sensitive probe for magnetic fields and fluctuations. While the magnetic dynamics of non-interacting xy moments are described by one time scale determined by the superparamagnetic blocking, strongly interacting macrospins develop partial static order at temperatures where non-interacting single particles still fluctuate. In this regime, the dynamics are described by two time scales related to the strong correlations due to a cooperative phase transition.

MA 44.5 Wed 16:00 HSZ 403

Evidence for possible quantum spin-ice behaviour in Pr2Hf2O7 as seen by inelastic neutron scattering. — •Alexandros Samartzis[1], Vivek K. Anand[1], Nazmul A.T.M. Islam[1], Andrew Wildes[2], Robert Bewley[3], Andrey A. Podlesnyak[4], David Voneshen[3], and Bella Lake[1] — [1]Helmholtz-Zentrum Berlin, Germany — [2]Institute Laue-Langevin, France — [3]Rutherford Appleton Lab, UK — [4]Oak Ridge, National Lab, US

The rare earth pyrochlore systems are well known for their diverse magnetic ground state due to quintenssential lattice for frustration and Ising anisotropy. A delicate competition of crystal field, exchange and dipolar interactions can lead to exotic magnetic ground states, such as spin-ice. Pr-based pyrochlores are candidates of a new ground state named, quantum spin-ice, due to low magnetic moment of the non-Kramers Pr3+ ion. Recently, the low temperature macroscopic measurements of Pr2Hf2O7 as well as inelastic neutron scattering (INS) of powder sample have shown evidence for the realization of quantum spin-ice behavior (i.e. quantum fluctuations and slow spin-dynamics in the ground state etc). Motivated by the above interesting results, we extended the study using polarised and low energy neutron scattering with and without external field on a PHO single crystal, grown by the floating zone technique. The first results reveal the absence of any transition down to 85mK. Broad diffuse scattering and pinch points indicate increased quantum fluctuations. Inelastic data reveal a broad dispersionless magnetic excitation, with a narrow band gap which shifts to higher transferred energies by an applied field.

15 min. break.

MA 44.6 Wed 16:30 HSZ 403

Pseudo-Goldstone magnons in the Heisenberg helimagnet $ZnCr_2Se_4$. — •Yuliia Tymoshenko[1], Yevhen Onykiienko[1], Pavlo Portnichenko[1], Alistair Cameron[1], Doug Abernathy[2], Jacques Ollivier[3], Astrid Schneidewind[4], Vladimir Tsurkan[5], and Dmytro Inosov[1] — [1]TU Dresden, D-01069 Dresden, Germany — [2]ORNL, Oak Ridge, Tennessee 37831, USA — [3]ILL, 38042 Grenoble, France — [4]JCNS, D-85747 Garching, Germany — [5]University of Augsburg, 86135 Augsburg, Germany

Chromium spinels provide great opportunities to investigate magnetic interactions between classical spins on the almost ideal pyrochlore lattice. $ZnCr_2Se_4$ is a spinel compound with incommensurate spin-spiral ground state. In this talk we present inelastic neutron scattering measurements of magnetic excitations in $ZnCr_2Se_4$ over a wide range of energies in the whole Brillouin zone. Comparing our data with spin-dynamical calculations we have extracted exchange parameters up to the fourth nearest neighbour and found a good agreement with the isotropic Heisenberg model. Furthermore, measurements of low-energy helimagnon excitations performed in the single-domain spin spiral state revealed two distinct modes: the Goldstone mode emerging from incommensurate magnetic Bragg peaks and a soft pseudo-Goldstone mode emanating from an orthogonal wave vector.

MA 44.7 Wed 16:45 HSZ 403

Designing Kitaev spin liquids in metal-organic frameworks — •Masahiko G. Yamada, Hiroyuki Fujita, and Masaki Oshikawa — Institute for Solid State Physics, University of Tokyo, Kashiwa 277-8581, Japan

Kitaev's honeycomb lattice spin model is a remarkable exactly solvable model, which has a particular type of spin liquid as the ground state, which we call Kitaev spin liquid. Although its possible realization in iridates and α-$RuCl_3$ has been vigorously discussed recently, these materials have substantial non-Kitaev direct exchange interactions and do not show a spin liquid ground state. We theoretically propose new metal-organic frameworks (MOFs) with Ru^{3+} (or Os^{3+}) forming the honeycomb lattice as promising candidates for a more ideal realization of Kitaev-type spin models where the direct exchange interaction is strongly suppressed. The great flexibility of MOFs allows generalization to other three-dimensional lattices, for potential realization of a variety of spin liquids, including Weyl spin liquids. We argue that, in this class of materials, the degeneracy of the highest occupied molecular orbitals of the organic ligand implies a suppression of non-Kitaev interactions. As concrete examples, we estimate interactions in MOFs with oxalate-based (or tetraaminopyrazine-based) ligands, and show that they are promising candidates to realize Kitaev spin liquids.

MA 44.8 Wed 17:00 HSZ 403

Spectroscopic investigation of a spin liquid (RVB) state and local distortions in the frustrated spin-1/2 Copper Carbodiimide (CuNCN) — Azat Sharafeev[1], Vladimir Gnezdilov[2], •Peter Lemmens[1], Xiaohui Liu[3], Andrei Tchougreeff[3], and Richard Dronskowski[3] — [1]TU-BS, Braunschweig — [2]ILTP, Kharkov — [3]RWTH Aachen

In CuNCN there exist corrugated layers of Cu2+ bridged by NCN2-groups with a square planar Cu2+ coordination. Based on very large AF exchange and frustration a nonmagnetic ground state is observed. On the other side, some evidence for hidden magnetic order with strong fluctuations typical for low dimensionality has been given. We critically discuss the presently known scenarios on the basis of Raman scattering data, giving evidence for local lattice distortions for T<60K as well as high energy excitations. Work supported by RTG-DFG 1952/1, the Laboratory for Emerging Nanometrology, TU Braunschweig, and NTH Contacs in Nanosystems.

MA 44.9 Wed 17:15 HSZ 403

Comparison between dynamical permeability and permittivity in $Dy_2Ti_2O_7$ at low temperatures — •Steffen Harms[1], Christoph P. Grams[1], Martin Valldor[2], Johanna Frielingsdorf[1], Thomas Lorenz[1], and Joachim Hemberger[1] — [1]Institute of Physics II, University of Cologne, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

$Dy_2Ti_2O_7$ is one of the well known spin-ice compounds in which magnetic monopoles are emergent [1]. These monopoles carry electric dipoles [2] and therefore their dynamics is apparent in the dielectrical response $\varepsilon^*(\nu)$. Recently published data reveal the speeding up of a dielectric relaxation process reaching a relaxation rate of up to $\nu \sim$ 100 kHz near the critical endpoint of the (H,T)-phase diagram [3]. This process can be associated with the hopping of magnetic monopoles and should, among other contributions, leave a fingerprint in the magnetic ac-permeability. Here we present a comparative broadband study of complex permittivity and permeability in the mK range in order to disentangle the different contributions to the dynamic response in the spin ice $Dy_2Ti_2O_7$.

Funded through the Institutional Strategy of the University of Cologne within the German Excellence Initiative and the Deutsche Forschungsgemeinschaft through project HE-3129/2-1 and CRC

1238.
[1] C. Castelnovo et al., Nature 451, 42 (2008).
[2] D. I. Khomskii, Nature Communications 3, 1 (2012).
[3] C. P. Grams et al., Nature Communications 5, 4853 (2014).

MA 45: Focus Session: Magnon Transport in Metallic Spin Textures

Organizer: J. Fassbender (Helmholtz-Zentrum Dresden-Rossendorf e.V.)

While prototypes of magnonic logic gates have been demonstrated already on macroscopic length scales, magnonics going beyond wave-based information processing remains to be exploited to full extent. One of the current hot topics is magnon transport in and the interaction with magnetic spin textures such as domain walls, vortices and skyrmions. Both, magnons and spin textures, have common ground set by the interplay of dipolar-, spin-orbit- and exchange energies rendering them perfect interaction partners. Magnons are fast, sensitive to the spin directions and easily driven far from equilibrium. Spin textures are robust, non-volatile and still reprogrammable on ultrashort timescales.

Time: Wednesday 15:45–18:00 Location: HSZ 04

Invited Talk MA 45.1 Wed 15:45 HSZ 04
Manipulating Room Temperature Magnetic Skyrmions — •Axel Hoffmann — Materials Science Division, Argonne National Laboratory, Lemont, Illinois 60439, U.S.A.

Magnetic skyrmions are topologically distinct spin textures and can be stable with quasi-particle like behavior, where they can be manipulated with very low electric currents. Using magnetic multilayers we demonstrated that inhomogeneous charge currents allow the generation of skyrmions at room temperature in a process that is remarkably similar to the droplet formation in surface-tension driven fluid flows [1]. Micromagnetic simulations reproduce key aspects of this transformation process and suggest a possible second mechanism at higher currents that does not rely on preexisting magnetic domain structures [2]. Indeed, we demonstrated this second mechanism experimentally using non-magnetic point contacts. Using this approach, we demonstrated that the topological charge gives rise to a transverse motion on the skyrmions, i.e., the skyrmion Hall effect [3], which is in analogy to the ordinary Hall effect, which is due to the motion of electrically charged particles in the presence of a magnetic field.

This work was supported by the U.S. Department of Energy, Office of Science, Materials Sciences and Engineering Division.

[1] W. Jiang, et al., Science 349, 283 (2015).
[2] O. Heinonen, et al., Phys. Rev. B 93, 094407 (2016).
[3] W. Jiang, et al., Nature Phys., doi:10.1038/nphys3883 (2016).

Invited Talk MA 45.2 Wed 16:15 HSZ 04
Spin wave caustics and channelling in chiral spin systems — •Joo-Von Kim — Centre for Nanoscience and Nanotechnology (C2N), CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay, France

Spin waves are elementary excitations in magnetic systems and have attracted renewed attention due to possible applications in information processing. In ultrathin films and nanostructures, the presence of chiral interactions of the Dzyaloshinskii-Moriya form can lead to a number of interesting phenomena such as nonreciprocal propagation and channelling. We will present some recent theoretical work in this area, namely the appearance of caustics and interference patterns generated by a point source in continuous films [1], nonreciprocal channelling along chiral domain walls [2], and edge channelling states in nanostructured media [3]. These results may benefit future device development by illustrating how unidirectional flow of spin wave power can be achieved in realistic material systems.

This work was partially supported by the Agence Nationale de la Recherche (France) under contract numbers ANR-14-CE26-0012 (Ultrasky) and ANR-16-CE24-0027 (Swangate).

[1] J.-V. Kim *et al.*, Phys. Rev. Lett. **117**, 197204 (2016).
[2] F. Garcia-Sanchez *et al.*, Phys. Rev. Lett. **114**, 247206 (2015).
[3] F. Garcia-Sanchez *et al.*, Phys. Rev. B **89**, 224408 (2014).

15 min. break

Invited Talk MA 45.3 Wed 17:00 HSZ 04
Snell's Law for Spin Waves — •Johannes Stigloher[1], Martin Decker[1], Helmut Koerner[1], Kenji Tanabe[2], Takahiro Moriyama[3], Takuya Taniguchi[3], Hiroshi Hata[3], Marco Madami[4], Gianluca Gubbiotti[4], Kensuke Kobayashi[5], Teruo Ono[3], and Christian Back[1] — [1]University Regensburg , Regensburg, Germany — [2]Nagoya University, Nagoya, Japan — [3]Kyoto University, Uji, Japan — [4]Universita di Perugia, Perugia, Italy — [5]Osaka University, Osaka, Japan

Snell's law is well known in optics and describes refraction of light at the transition between two media with different dispersion relations. In our experiments, we model this transition by a thickness step in a ferromagnetic material. Spin waves are excited in a Permalloy film of 60 nm thickness and propagate into a film of 30 nm thickness. Since these two regions have different dispersion relations [1-3] we are able to observe Snell's law for spin waves by measuring the refraction for a variety of samples with varying incident angles [3]. Snell's law for spin waves deviates from Snell's law in optics, since the spin wave dispersion relation is anisotropic, i.e. it depends strongly on the angle of propagation direction with respect to the external field [4].

[1] K. Tanabe et al., Appl. Phys. Exp. 7, 053001 (2014). [2] J.N. Toedt et al., Phys Rev B 93, 184416 (2016). [3] J. Stigloher et al., Phys. Rev Lett., 117,037204 (2016). [3] B.A. Kalinikos and A.N. Slavin, J. Phys. D: Solid State Physics 19, 7013 (1986).

MA 45.4 Wed 17:30 HSZ 04
Magnon-skyrmion scattering in chiral magnets — •Markus Garst — Institut für Theoretische Physik, Technische Universität Dresden, Zellescher Weg 17, 01062 Dresden, Germany

Chiral magnets support topological skyrmion textures due to the Dzyaloshinskii-Moriya spin-orbit interaction. We discuss the interaction between such a magnetic skyrmion and its small-amplitude fluctuations, i.e., the magnons in a two-dimensional chiral magnet. The magnon spectrum includes few magnon-skyrmion bound states, in particular, a breathing mode and a quadrupolar mode, which will give rise to subgap magnetic and electric resonances. Due to the skyrmion topology, the magnons scatter from an emergent flux density that leads to skew and rainbow scattering, characterized by an asymmetric and oscillating differential cross section. As a consequence of the skew scattering, a finite density of skyrmions will generate a topological magnon Hall effect. Using the conservation law for the energy-momentum tensor, we demonstrate that the magnons also transfer momentum to the skyrmion. As a consequence, a magnon current leads to magnon pressure reflected in a momentum-transfer force in the Thiele equation of motion for the skyrmion. This force is reactive and governed by the transport scattering cross sections of the skyrmion; it causes not only a finite skyrmion velocity but also a large skyrmion Hall effect.

[1] C. Schütte and M. Garst, Phys. Rev. B 90, 094423 (2014)
[2] S. Schroeter and M. Garst, Low. Temp. Phys. 41, 817 (2015)

MA 45.5 Wed 17:45 HSZ 04
Frequency-division multiplexing in magnonic networks by spin-wave caustics — •Frank Heussner, Alexander A. Serga, Burkard Hillebrands, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Frequency-division multiplexing is the basis for parallel data processing in a single device and for efficient information transport through logic circuits. In such networks, signals at different frequencies are used to simultaneously transfer information through the same conduits in different frequency channels.

In this work, we present an approach for the realization of frequency-division multiplexing in magnonic networks, where spin waves (SW) are used to transport information and to perform logic operations by exploiting, e.g., interference effects. In particular, we utilize non-diffractive spin-wave beams in in-plane magnetized 2D magnetic media, so called SW caustics, which originate from the anisotropic SW dispersion. By using micromagnetic simulations, we demonstrate how the frequency dependency of the propagation direction of SW caustics can be used to split SW signals of different frequencies into different SW waveguides. Finally, we present the design of a passive device at the micrometer scale which performs frequency-division multiplexing in a magnonic network.

Financial support by DFG within project SFB/TRR 173 Spin+X is gratefully acknowledged.

MA 46: Focus Session on 2D Materials: Ballistic Quantum Transport in Graphene (jointly with DY, DS, HL, MA, O)

Ballistic electron waves yielded a plethora of insights already in 2D semiconducting heterostructures. Recent experimental techniques have paved the way to this regime also for graphene. The massless, relativistic, and chiral nature of its charge carriers enriches ballistic transport by qualitatively new physical phenomena, such as ambipolar states near pn-junctions, Klein tunneling, or a zeroth Landau level in a perpendicular magnetic field. This session will review the actual status.

Organisation: Wolfgang Häusler, Universität Augsburg; Reinhold Egger, Universität Düsseldorf; Klaus Richter, Universität Regensburg

Time: Thursday 9:30–13:00 Location: HSZ 03

Invited Talk MA 46.1 Thu 9:30 HSZ 03
Kondo Screening of a Vacancy Magnetic Moment in Graphene — •Eva Y. Andrei — Dept. of Physics, Rutgers University, Piscataway, NJ

Graphene in its pristine form has transformed our understanding of 2D electron systems leading to fundamental discoveries and to the promise of important applications. When the perfect honeycomb lattice of graphene is disrupted by single atom vacancies new phenomena emerge including the buildup of local charge and the appearance of a local moment. Using scanning tunneling microscopy to identify Kondo screening of the vacancy moment by its spectroscopic signature, we demonstrate that the local magnetic moment can be controlled either by doping or through the local curvature. This allows to detect and map the quantum phase transition separating magnetic from non-magnetic states in this pseudogap system.

Invited Talk MA 46.2 Thu 10:00 HSZ 03
Higher-Than-Ballistic Conduction in Viscous Electron Fluids — •Leonid Levitov — Physics Department, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge MA02139

This talk will argue that in viscous electron flows interactions facilitate transport, allowing conductance to exceed the fundamental Sharvin-Landauer quantum-ballistic limit. The effect is particularly striking for the flow through a viscous point contact, a constriction exhibiting the quantum-mechanical ballistic transport at zero temperature but governed by electron hydrodynamics at elevated temperatures. The crossover between the ballistic and viscous regimes occurs when the mean free path for e-e collisions becomes comparable to the constriction width. Further, we will discuss the negative nonlocal response, a signature effect of viscous transport. This response exhibits an interesting nonmonotonic behavior vs. temperature at the viscous-to-ballistic transition. The response is negative but small in the highly viscous regime at elevated temperatures. The value grows as the temperature is lowered and the system becomes less viscous, reaching the most negative values in the crossover region where the mean free path is comparable to the distance between contacts. Subsequently, it reverses sign at even lower temperatures, becoming positive as the system enters the ballistic regime. This peculiar behavior provides a clear signature of the ballistic-to-viscous transition and enables a direct measurement of the electron-electron collision mean free path.

Invited Talk MA 46.3 Thu 10:30 HSZ 03
Electron Optics in Ballistic Graphene — •Ming-Hao Liu — Department of Physics, National Cheng Kung University

Electrons in clean graphene are known to behave like "charged photons" due to its celebrated energy dispersion linear in momentum, providing an ideal platform for exploring electron optics. Despite the discovery of graphene in 2004, devices of ultraclean samples with micron-scale mean free paths became accessible only recently. Reliable quantum transport simulations in the ballistic limit for understanding and predicting high-quality transport experiments have therefore become increasingly demanded nowadays. In this talk, an overview of our recent progress on simulating a variety of ballistic graphene transport experiments will be given, such as Fabry-Pérot interference, snake states, and gate-defined electron waveguides [1]. Keys to such quantum transport simulations will be briefly introduced [2]. Ongoing works possibly including *pnp* junctions in the presence of 2D Moiré superlattice and Weiss oscillation due to 1D periodic gating will be mentioned at the end of the talk.

[1] P. Rickhaus *et al.*, Nat. Communs. **4**, 2342 (2013); M. Drienovsky *et al.*, Phys. Rev. B **89**, 115421 (2014); A. Varlet *et al.*, Phys. Rev. Lett. **113**, 116601 (2014); P. Rickhaus *et al.*, Nat. Communs. **6**, 6470 (2015); P. Rickhaus *et al.*, Nano Lett. **15**, 5819 (2015).
[2] M.-H. Liu *et al.*, Phys. Rev. Lett. **114**, 036601 (2015).

15 min. break.

Invited Talk MA 46.4 Thu 11:15 HSZ 03
Ballistic Transport in Mesoscopic Graphene Devices — •Christoph Stampfer — JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany — Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany

The recent technological advances in encapsulating graphene by hexagonal boron nitride forming artificial van-der-Waals heterostructures allows the fabrication of graphene devices with high electronic quality. Outstanding charge carrier mobilities and mean free paths with more than 10 micrometer are now accessible making this material stack interesting for studying ballistic transport. By further structuring the graphene-hBN based heterostructures mesoscopic devices can be fabricated on which phase coherent ballistic quantum transport can be studied.

Here, I will present low-temperature magneto-transport measurements on both (i) graphene quantum point contacts and (ii) high mobility graphene rings encapsulated in hexagonal boron nitride. Our experiments allow to extract information on quantized conductance, renormalized Fermi velocities close to the charge neutrality point as well as the co-existence of weak localization, Aharonov-Bohm oscillations and universal conductance fluctuations in graphene rings.

Invited Talk MA 46.5 Thu 11:45 HSZ 03
Interaction-Induced Conductance from Zero Modes in a Magnetic Graphene Waveguide — •Alex Zazunov — Heinrich-Heine-Universität Düsseldorf

We consider a waveguide formed in a clean graphene monolayer by a spatially inhomogeneous magnetic field. The single-particle dispersion relation for this waveguide exhibits a zero-energy Landau-like flat band, while finite-energy bands have dispersion and correspond, in particular, to snake orbits. For zero-mode states, all matrix elements of the current operator vanish, and a finite conductance can only be caused by virtual transitions to finite-energy bands. We show that Coulomb interactions generate such processes. In stark contrast to finite-energy bands, the conductance is not quantized and shows a characteristic dependence on the zero-mode filling. Transport experiments thereby offer a novel and highly sensitive probe of electron-electron interactions in clean graphene samples.

MA 46.6 Thu 12:15 HSZ 03

Ballistic thermophoresis on graphene — •Emanuele Panizon[1], Roberto Guerra[1,2], and Erio Tosatti[1,2,3] — [1]SISSA, Trieste, Italy — [2]CNR-IOM Democritos, Trieste, Italy — [3]ICTP, Trieste, Italy

The textbook thermophoretic force acting on a diffusing body in a fluid is proportional to the local temperature gradient. This is not the case for a diffusing physisorbed body on a submicron sized 2D suspended layer. A Non-Equilibrium Molecular Dynamics study of a test nanosystem - a gold nanocluster adsorbed on a single graphene sheet of length L clamped between two temperatures ΔT apart - reveals a phoretic force that is parallel to, but essentially independent of, the gradient magnitude $\Delta T/L$ up to a substantial L of $150nm$.

This is argued to represent ballistic thermophoresis, where the force is provided by the flux of massively excited flexural phonons, whose flow is in turn known to be ballistic and distance-independent up to relatively long scattering lengths before the eventual onset of the more standard diffusive regime. The surprising thrust and real momentum provided by the flexural modes are analysed and understood in terms of the large mass non/uniformity involved with these modes. The ensuing surf-riding of adsorbates on the vibrating 2D hard sheet, and the resulting gradient independent thermophoretic force, are not unlikely to possess practical applications.

MA 46.7 Thu 12:30 HSZ 03

Quantum time mirrors in two-band systems with and without broken time-reversal symmetry — •Phillipp Reck[1], Cosimo Gorini[1], Arseni Goussev[2], Viktor Krueckl[1], Mathias Fink[3], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg — [2]Department of Mathematics, Physics and Electrical Engineering, Northumbria University, Newcastle Upon Tyne, UK — [3]Institut Langevin, ESPCI, CNRS, PSL Research University, Paris

Both metaphysical and practical considerations intrigued generations of scientists to devise and implement time-inversion protocols – in particular the Hahn echo [1], different forms of "time mirrors" for classical waves (see e.g. [2]), and recently an instantaneous time mirror for water waves [3]. With our proposal for an instantaneous Quantum Time Mirror [4], we showed the possibility to extend the family of time reversal protocols to *continuous quantum* systems, more precisely to wave packets in Dirac-cone systems, by changing the propagation direction with a short, time-dependent pulse.

In this talk, we discuss the effect on the Quantum Time Mirror of both, a static, out-of-plane magnetic field, which breaks time-reversal symmetry, and band structures other than the Dirac cone, e.g. the valence and conduction bands in direct gap semi-conductors.

[1] E. L. Hahn, Spin echoes. Phys. Rev.. 80, 580 (1950)
[2]M. Fink, IEEE Trans. Ultrason. Ferroelectr. Freq. Control, 39, 555, (1992)
[3]V. Bacot, et al., Nat. Phys. 12, 972–977 (2016)
[4]P. Reck, et al., arXiv:1603.07503 (2016)

MA 46.8 Thu 12:45 HSZ 03

Current flow paths in deformed graphene and carbon nanotubes — Erik Kleinherbers, •Nikodem Szpak, and Ralf Schützhold — Faculty of Physics, University of Duisburg-Essen, Germany

Due to imminent applications in nanoelectronics it is of high interest to understand the precise conductance properties of deformed graphene and bent carbon nanotubes. Since low-energy electronic excitations behave like massless Dirac fermions the current flow can be approximated semiclassically and used as a guide in the design of conducting nanoelectronic elements and nanosenors. Taking into account the curvature effects as well as an emerging inhomogeneous pseudo-magnetic field we calculate the current flow paths theoretically and compare them with numerical simulations of the full electronic transport.

MA 47: Spin Hall Effects and Skyrmions I

Time: Thursday 9:30–13:15 Location: HSZ 04

MA 47.1 Thu 9:30 HSZ 04

Topological orbital ferromagnets — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spontaneous orbital magnetism in ferromagnets is conventionally explained as a key manifestation of the spin-orbit interaction lifting partially the orbital moment quenching. While such an interpretation applies to most condensed-matter systems, it fails to describe orbital magnetism in crystals exhibiting a finite *topological* orbital magnetization (TOM) without any reference to spin-orbit coupling. In these systems an emergent magnetic field rooting in the noncoplanarity of neighboring spins replaces the spin-orbit interaction as the main mechanism lifting the orbital degeneracy by coupling to the orbital degrees of freedom. The nontrivial topology of this spin texture further gives rise to the topological Hall effect, which is closely related to the TOM both from microscopic and symmetry considerations. Here, we predict from first principles a sizable magnitude of TOM and topological Hall effect (i) in the spin-compensated thin film Mn/Cu(111) and (ii) in the antiferromagnetic bulk material γ-FeMn, both of which reveal noncoplanar spin textures in real space. We demonstrate that these systems are prototypical topological orbital ferromagnets [1,2] for which the macroscopic magnetization is completely dominated by orbital magnetism prominent even in absence of spin-orbit interaction.

[1] J.-P. Hanke *et al.*, Phys. Rev. B **94**, 121114(R) (2016).
[2] J.-P. Hanke *et al.*, Sci. Rep. (submitted, 2016).

MA 47.2 Thu 9:45 HSZ 04

Crossover between mechanisms of skyrmion annihilation in a racetrack — •Pavel Bessarab[1], Igor Lobanov[2], Gideon Müller[3], Filipp Rybakov[4], Nikolai Kiselev[3], Stefan Blügel[3], Lars Bergqvist[5], and Anna Delin[5] — [1]University of Iceland, Reykjavík, Iceland — [2]ITMO University, St. Petersburg, Russia — [3]Forschungszentrum Jülich, Jülich, Germany — [4]Institute of Metal Physics, Ekaterinburg, Russia — [5]KTH Royal Institute of Technology, Kista, Sweden

Theoretical calculations of thermal stability of skyrmions in a PdFe bilayer strip on an Ir(111) substrate are presented. The lifetime of a skyrmion at a given temperature is identified using harmonic transition state theory for spins [1]. The energy barriers are obtained from minimum energy paths (MEPs) for skyrmion annihilation and pre-exponential factors are estimated from the curvature of the energy surface. The MEP calculations [2] revealed two mechanisms of skyrmion annihilation in the strip: escape through the boundary and radial collapse at the interior. At low external fields, the escape mechanism prevails, but a crossover field exists, above which the collapse mechanism becomes dominant, defining the skyrmion stability. This analysis provides a deeper understanding of skyrmion formation and stability and helps develop ways to control magnetic skyrmions in novel devices.

[1] P.F. Bessarab, V.M. Uzdin, H. Jónsson, *Phys. Rev. B*, **85**, 184409 (2012).
[2] P.F. Bessarab, V.M. Uzdin, H. Jónsson, *Comput. Phys. Commun.*, **196**, 335 (2015).

MA 47.3 Thu 10:00 HSZ 04

Magnetic phase transitions in skyrmion host GaV_4Se_8 established by magnetocurrent measurements — Adam Butykai[1,2], •Sandor Bordács[1,2], Miklos Csontos[1], Vladimir Tsurkan[3], and Istvan Kezsmarki[1,2] — [1]Department of Physics, Budapest University of Technology and Economics, Budafoki út 8., Budapest, Hungary — [2]MTA-BME Lendület Magneto-optical Spectroscopy Research Group — [3]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

GaV_4Se_8 (GVSe) is a member of the lacunar spinel family, a sister compound to GaV_4S_8 (GVS), wherein the emergence of a Néel-type skyrmion lattice phase has been reported [1]. The supposedly lower magnetic anisotropy in GVSe is expected to stabilize the modulated magnetic structures down to lower temperatures against the uniform ferromagnetic phase.

Similarly to GVS, the Selenide compound is also a magnetoelectric multiferroic (with a Curie-temperature of T_C=19K), therefore the cycloidal spirals and the magnetic skyrmions are expected to carry magnetoelectric polarization, as demonstrated for GVS [2].

Magnetcurrent and pyrocurrent measurements were performed to detect the magnetic phase transitions in GVSe in two principal directions of the external magnetic field. A tentative magnetic phase diagram has been established, indicating an extended cycloidal and skyrmion lattice phase.

[1] Kezsmarki, I. et al. Nature materials 14, (2015) [2] Ruff, E. et al. Science advances 1, (2015)

MA 47.4 Thu 10:15 HSZ 04

Annihilation of magnetic skyrmions by quantum tunneling

— •Sergei Vlasov[1,2], Pavel F. Bessarab[1,2], Igor S. Lobanov[2], Maria Potkina[3], Valery M. Uzdin[2,3], and Hannes Jónsson[1] — [1]University of Iceland, Reykjavík, Iceland — [2]University ITMO, St. Petersburg, Russia — [3]St. Petersburg State University, St. Petersburg, Russia

Magnetic skyrmions are localized, noncollinear spin configurations which are topological solitons. In discrete systems, a skyrmion state is separated from the ferromagnetic state by a finite energy barrier and transitions between these states can occur by jumps over the barrier or by quantum mechanical tunnelling. The rate of such transitions is an important consideration when the stability of skyrmions is assessed for data storage devices.

As the temperature is lowered, quantum tunneling becomes the dominant transition mechanism. The shift from thermally activated jumps to tunnelling is analysed and a general expression derived for the crossover temperature in terms of the second derivatives of the energy with respect to the orientations of the spin vectors at the saddle point. The expression is an extension of the theory for single spin onset temperature [S. Vlasov et al., Faraday Discussions DOI: 10.1039/c6fd00136j]. Skyrmion onset temperature is evaluated for an extened Heisenberg Hamiltonian representing a Co monolayer on Pt(111) for which the thermal jump rate has recently been calculated using a harmonic approximation to transition state theory [I.S. Lobanov et al., Phys. Rev. B 94, 174418 (2016)] and found to be 3 K.

MA 47.5 Thu 10:30 HSZ 04

Relaxation dynamics between the modulated magnetic phases of GaV_4S_8 investigated by ac-susceptibility measurements

— •Bertalan György Szigeti[1], Ádám Butykai[1], Sándor Bordács[1,2], László Ferenc Kiss[3], and István Kézsmárki[1,2] — [1]Department of Physics, Budapest University of Technology and Economics, Budafoki út 8., Budapest, Hungary — [2]MTA-BME Lendület Magneto-optical Spectroscopy Research Group — [3]Wigner Research Centre for Physics, Budapest, Hungary

GaV_4S_8 is a multiferroic semiconductor, known to be the first bulk material with a non-chiral crystal structure to host (Néel-type) magnetic skyrmions [1]. Below its Curie-temperature, T_C=13 K, the compound features cycloidal spin spirals, a skyrmion lattice phase and a uniform ferromagnetic phase in increasing magnetic fields. The field-induced phase transitions involve the rearrangement of large magnetic structures, therefore the magnetic relaxation occurs on enhanced, often macroscopically large timescales. Here, a systematic study of the frequency-dependent ac-susceptibility of the material is presented, also discussing the temperature dependence of the relaxation time at the phase boundaries.

[1] I. Kézsmárki et al., Nat. Mater.14, 1116 (2015)

MA 47.6 Thu 10:45 HSZ 04

Topological Spin Hall Effect in Antiferromagnetic Skyrmions

— •Patrick M. Buhl, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute of Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We report on our recent methodological developments designed to describe the transport properties of large-scale chiral magnetic structures on the basis of a Boltzmann-like semiclassical formalism. Density-functional theory is used to supply an accurate initial collinear description of our antiferromagnetic example systems such as Fe/Cu/Fe trilayer. On top, skyrmionic long-range chiral magnetic texture is artificially imposed on the level of degenerate, and thus non-abelian, equations of motion, in which the topological non-triviality manifests as the emergent magnetic field. Within this framework, we iteratively find the wave-packet semiclassical trajectories for the states at the Fermi surface in order to estimate the conductivity tensor. Thereby we gain an important insight into the macroscopic transport properties of two-dimensional chiral magnetic structures and can quantify their sizeable topological spin Hall effect. This work is supported by SFB1238.

15 min. break.

MA 47.7 Thu 11:15 HSZ 04

Absence of detectable current-induced magneto-optical Kerr effects in Pt, Ta and W

— •Patricia Riego[1], Saül Vélez[1], Juan M. Gomez-Perez[1], Jon Ander Arregi[1], Luis E. Hueso[1,2], Fèlix Casanova[1,2], and Andreas Berger[1] — [1]CIC nanoGUNE, San Sebastian (Spain) — [2]Ikerbasque, Bilbao (Spain)

The direct detection of spin accumulation arising from the spin Hall effect (SHE) in metals via the magneto-optical Kerr effect (MOKE) would enable an easily accessible methodology for spintronics phenomena. Prior works have performed such measurements and have reported a successful outcome [1]. Here, we explore such possibility by means of generalized magneto-optical ellipsometry (GME), a MOKE-based method that, in contrast to conventional MOKE measurement schemes, allows for a clear identification of the magneto-optical (MO) nature of the signal. We have performed measurements for three different materials: Pt, W, and Ta, and we observe a current-induced change in the light intensity in all of them. However, our complete GME analysis shows that such current-induced effects are not MO in nature, and therefore do not arise from a SHE-induced light polarization signal in any of the materials. Instead, they constitute a purely optical signal that arises from a heating-induced change in reflectivity. Based on the sensitivity achieved in our experiments, we conclude that state-of-the-art MO methods utilizing linear optics are not sufficiently sensitive to detect SHE-induced spin accumulation in these metals [2].

[1] O. M. J. van't Erve et al., Appl. Phys. Lett. 104, 172402 (2014). [2] P. Riego et al., Appl. Phys. Lett. 109, 172402 (2016).

MA 47.8 Thu 11:30 HSZ 04

Current induced manipulation of the staggered magnetization of an antiferromagnet

— •Stanislav Bodnar, Martin Jourdan, Hans-Joachim Elmers, and Mathias Kläui — Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

Novel concepts for ultrafast spintronics rely on antiferromagnets (AFMs), e.g. by employing the direction of their staggered magnetization for data storage. Thus, new approaches for the manipulation of the AFM spin-orientation beyond magnetic fields need to be established. Considering the tetragonal AFM compound Mn2Au, current densities of 108-109 A/cm2 were estimated to reorient the spin-axis via spin-orbit torques [Zel14]. We prepared epitaxial thin films of Mn2Au [Jou15] and investigated the possibility to reorient the antiferromagnetic domains by the application of short current pulses. Our measurements of the planar Hall effect and longitudinal resistance of these sample show clear dependencies on the direction of previously applied current pulses, thus provided strong evidence for current induced manipulation of the Néel vector.

[Zel14]*J. Železný, H. Gao, K. Výborný, J. Zemen, J. Mašek, A. Manchon, J. Wunderlich, J. Sinova, T. Jungwirth, Phys. Rev. Lett. 113, 157201 (2014). [Jou15] M. Jourdan, H. Bräuning, A. Sapozhnik, H.-J. Elmers, H. Zabel and M. Kläui, J. Phys. D: Appl. Phys. 48, 385001 (2015).

MA 47.9 Thu 11:45 HSZ 04

Temperature dependence of the spin Hall angle and switching current in the nc-W(O)/CoFeB/MgO system with perpendicular magnetic anisotropy

— Lukas Neumann, Daniel Meier, Jan Schmalhorst, Karsten Rott, Günter Reiss, and •Markus Meinert — Center for Spinelectronic Materials and Devices, Bielefeld University, Bielefeld, Germany

We investigated the temperature dependence of the switching current for a perpendicularly magnetized CoFeB film deposited on a nanocrystalline tungsten film with large oxygen content: nc-W(O). The effective spin Hall angle $|\Theta_{\mathrm{SH}}^{\mathrm{eff}}| \approx 0.22$ is independent of temperature, whereas the switching current increases strongly at low temperature. The increase can not be explained by the increased coercive field, but rather indicates that the current induced switching itself is thermally activated, in agreement with a recent theoretical prediction. The dependence of the switching current on the in-plane assist field suggests the presence of an interfacial Dzyaloshinskii-Moriya interaction with $D \approx 0.23\,\mathrm{mJ/m^2}$, intermediate between the Pt / CoFe and Ta / CoFe systems. We show that the nc-W(O) is insensitive to annealing, which makes this system a good choice for the integration into magnetic memory or logic devices that require a high-temperature annealing process during fabrication.

MA 47.10 Thu 12:00 HSZ 04

Novel spin currents in non-collinear antiferromagnets — •Jakub Zelezny[1], Yang Zhang[1,2], Claudia Felser[1], and Binghai Yan[1,3] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Many key spintronics phenomana are caused by spin currents. Here we study spin currents in non-collinear antiferromagnets Mn3Sn and Mn3Ir. It was recently demonstrated that a large spin Hall effect exists in these materials. We show by symmetry analysis and microscopic ab-initio calculations that in these antiferromagnets, also a different type of spin currents occur, which have an origin and symmetry distinct from the spin Hall effect. These spin currents are similar to spin-polarized currents in ferromagnets, however, unlike in ferromagnets, they also contain a transversal contribution (i.e., a spin current flowing in the direction transversal to the charge current). Our calculations reveal that both the spin-polarized currents and the transversal spin currents are large in the studied materials. These spin currents could have important applications since the effects that originate from the spin-polarized current in ferromagnets, like the tunneling magnetoresistance or the spin-transfer torque, will also be present in the non-collinear antiferromagnets. Furthermore, the transversal spin currents will contribute to the spin-orbit torque generated by the spin Hall effect.

MA 47.11 Thu 12:15 HSZ 04

Optimizing the spin Hall angle above 100% — •Christian Herschbach[1], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]University of Bristol, Bristol, United Kingdom

The spin Hall effect (SHE) is one of the key effects in modern spintronics creating pure spin currents directly in nonmagnetic materials. The effect's strength is usually quantified with the so-called spin Hall angle (SHA), which is the ratio of the transverse spin conductivity to the longitudinal charge conductivity. Reported values based on both experimental and theoretical investigations increased during the last years. Measurements on Pt-doped Au samples yielded a SHA of about 10% introduced as giant SHE [1] while a SHA of 24% was published for thin-film Cu(Bi) alloys [2]. The large effect caused by Bi impurities in Cu was theoretically predicted for bulk samples [4]. Further theoretical investigations on Bi-doped ultrathin noble-metal films forecast *colossal* SHAs slightly below 100% [5].

In this work we further investigate the possibility to optimize the SHE. We identify systems with a strong anisotropy of the in-plane transport properties that lead to SHAs above 100%.

[1] Seki *et al.*, Nat. Mater. **7**, 125 (2008)
[2] Niimi *et al.*, Phys. Rev. Lett. **109**, 156602 (2012)
[3] Pai *et al.*, Appl. Phys. Lett. **101**, 122404 (2012)
[4] Gradhand *et al.*, Phys. Rev. Lett. **104**, 186403 (2010)
[5] Herschbach *et al.*, Phys. Rev. B **90**, 180406(R) (2014)

MA 47.12 Thu 12:30 HSZ 04

Tuning spin Hall angles by alloying — •S. Wimmer[1], K. Chadova[1], D. Ködderitzsch[1], M. Obstbaum[2], M. Decker[2], A. K. Greitner[2], M. Härtinger[2], T. N. G. Meier[2], M. Kronseder[2], C. H. Back[2], and H. Ebert[1] — [1]Department Chemie, Ludwig-Maximilians-Universität München — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg

Within a combined experimental and theoretical study it could be shown that the spin Hall angle of a substitutional alloy system can be continuously varied via its composition [1]. For Au_xPt_{1-x} a substantial increase of the maximum spin Hall angle compared to the pure alloy partners could be achieved. The experimental findings for longitudinal charge conductivity σ_{xx}, transverse spin Hall conductivity σ^z_{xy}, and spin Hall angle α_{SH} could be confirmed by calculations based on the Kubo-Bastin formula [2] implemented in a KKR-CPA framework. Calculations of these response quantities for different temperatures using the so-called Alloy-Analogy Model [3] show that the divergent behavior of σ_{xx} and σ^z_{xy} is rapidly suppressed with increasing temperature T. As a consequence, σ^z_{xy} is dominated at higher T by its intrinsic contribution that has only a rather weak temperature dependence. Detailed analysis of the scaling behavior of $\sigma^z_{xy}(x,T)$ w.r.t. $\sigma_{xx}(x,T)$ moreover reveals that the extrinsic contribution changes sign as a function of T in the dilute limit $x \to 0$.

[1] M. Obstbaum *et al.*, *Phys. Rev. Lett.* **117**, 167204 (2016). [2] A. Bastin *et al.*, *J. Phys. Chem. Solids* **32**, 1811 (1971). [3] H. Ebert *et al.*, *Phys. Rev. B* **91**, 165132 (2015).

MA 47.13 Thu 12:45 HSZ 04

Skyrmions with attractive interactions in an ultrathin magnetic film — •Levente Rózsa[1], András Deák[2], Eszter Simon[2], Rocio Yanes[3], László Udvardi[2], László Szunyogh[2], and Ulrich Nowak[3] — [1]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]Universität Konstanz, Konstanz, Germany

Magnetic skyrmions in ultrathin films, corresponding to localized noncollinear spin structures, hold promising aspects in future data storage and spintronics applications[1]. Besides chiral skyrmions stabilized by the Dzyaloshinsky–Moriya interaction, the frustration of the isotropic exchange interactions may also lead to the formation of skyrmions[2]. We performed *ab initio* electronic structure calculations to determine the parameters in a classical spin Hamiltonian describing an Fe monolayer on Pd(111) surface with a $Pt_{1-x}Ir_x$ alloy overlayer. We demonstrate that increasing the Ir concentration x transforms the ground state from ferromagnetic into a spin spiral state, primarily due to the increased frustration of the isotropic exchange interactions. Using spin dynamics simulations, we show that the isolated skyrmions observed in the collinear phase form clusters due to the short-range attractive interaction between them, and that these clusters remain stable against thermal fluctuations[3].

[1] A. Fert *et al.*, Nat. Nanotech. **8**, 152 (2013).
[2] A. O. Leonov *et al.*, Nat. Commun. **6**, 8275 (2015).
[3] L. Rózsa *et al.*, Phys. Rev. Lett. **117**, 157205 (2016).

MA 47.14 Thu 13:00 HSZ 04

Spin-torque and fluctuation-dissipation at FM-AFM tunnelling junctions — •Kei Yamamoto[1,2], Georg Schwiete[3,1], Olena Gomonay[1,4], and Jairo Sinova[1,5] — [1]Institut für Physik, Johannes Gutenberg Universität, 55128 Mainz, Germany — [2]Institute for Material Research, Tohoku University, Sendai 980-8577, Japan — [3]Department of Physics and Astronomy and Center for Materials for Information Technology, The University of Alabama, Tuscaloosa, AL 35487 — [4]National Technical University of Ukraine "KPI", 03056, Kyiv, Ukraine — [5]Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnicka 10, 162 00 Praha 6, Czech Republic

Antiferromagnetic materials (AFM) are emerging as a promising candidate to be a fundamental building block of next generation spintronic devices. One of the highlights from recent experimental findings is their peculiar spin transport characteristics. In ferromagnetic-antiferromagnetic heterostructures, spin pumping measurements revealed a strong temperature dependence of AFM spin conductivity, while their spin-Hall magnetoresistance indicates that AFM can be as good a sink of spin as ferromagnetic materials (FM).

In this talk, I present a microscopic description of non-equilibrium spin transport through FM-AFM tunneling junctions. Employing path integral formulation of quantum statistical mechanics, one can derive formulas for spin torque, spin pumping and the power spectrum of spin current fluctuations at the junction in a single unified framework. As an application, the AFM magnetic moment fluctuation induced by a steady voltage/temperature bias is computed.

MA 48: Spin Dynamics and Transport: Spin Excitations and Spin Torque Phenomena

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

MA 48.1 Thu 9:30 HSZ 101

Micron sized tapered spin hall oscillators under the influence of external microwave signals — •Kai Wagner[1,2], Andrew Smith[3], Tobias Hula[1], Toni Hache[1], Jürgen Lindner[1], Ilya Krivorotov[3], and Helmut Schultheiss[1,2] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, D-01328, Germany — [2]TU Dresden, D-01062 Dresden, Germany — [3]Department of Physics and Astronomy, University of California, Irvine, California, USA.

We investigate by Brillouin-Light-Scattering microscopy the spatial dependent auto-oscillation spectra of tapered permalloy wires [1] when subjected to spin-orbit-torques generated via the spin hall effect in an underlying Platinum layer. We first identify the different spectral contributions to the integral auto-oscillation signal across the spatially varying SHO. Subsequently the influence of external microwave signals on these spectra are investigated. Strongly amplified signals are observed, when the microwave frequency matches those of the auto-oscillations even for microwave powers, which are sufficiently small to not excite magnetisation dynamics outside of the auto-oscillatory regime. We believe this can be attributed to locking of the non-isochronus SHO to the external microwave signals resulting in spectrally narrower auto-oscillations with differing spatial extend. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

[1]: Liu Yang et al. , Scientific reports **5**, 16942 EP, 2015

MA 48.2 Thu 9:45 HSZ 101

Spin-wave heating vs. Joule heating in spin-Hall-effect and spin-transfer-torque driven Cr|Heusler|Pt waveguides — •Thomas Meyer[1], Philipp Pirro[1], Thomas Brächer[1,3], Frank Heussner[1], Alexander Serga[1], Hiroshi Naganuma[2], Koki Mukaiyama[2], Mikihiko Oogane[2], Yasuo Ando[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan — [3]current affiliation: Université Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, 38054 Grenoble, France

We present time-resolved Brillouin light scattering measurements on spin-Hall-effect and spin-transfer-torque driven magnetization dynamics in a microstructured Cr|Heusler|Pt waveguide. Reducing the effective spin-wave damping, a strong increase in the magnon density is observed which is accompanied by a reduction of the spin-wave frequency. By evaluating the temporal behavior of these effects and comparing these to COMSOL multiphysics simulations, we can identify spin waves as the main heating source in the investigated structure. Correlating the spin-wave frequency to the magnon density for different applied current values proves that Joule heating by the applied current can be neglected. The results show that, in any application using the spin-transfer torque effect, the contribution to the temperature increase by an increased magnon density needs to be considered. Financial support by the DFG (TRR 173 'Spin+X') is acknowledged.

MA 48.3 Thu 10:00 HSZ 101

Parametric excitation of magnons in YIG films from cryogenic to above room temperatures — •Laura Mihalceanu[1], Vitaliy I. Vasyuchka[1], Dmytro A. Bozhko[1,2], Thomas Langner[1], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

Parameric pumping is a powerful tool to study fundamental properties of magnetization dynamics since it allows for the efficient excitation of magnons in a wide range of wavenumbers. By this, the efficient magnon injection into the spin system of yttrium iron garnet (YIG) films enabled the observation of such prominent phenomena as magnon Bose-Einstein condensates (BECs) and magnon supercurrents. Since until now all related experiments have been performed under normal ambient conditions, moving to cryogenic temperatures is of high interest, as a temperature decrease is expected to increase both the density and the lifetime of a magnon BEC significantly. The elongated BEC lifetime will allow to investigate the BEC's dynamics at long time scales and will help to reveal, e.g., such relatively slow effects as Josephson oscillations. As a first step toward low-temperature magnon BECs, we study the parametric excitation of dipolar and exchange magnons in the temperature range from 40 K to 340 K. We address the impact of temperature on the saturation magnetization and reveal the behavior of the magnon relaxation parameter on the wide temperature scale.

The work is supported by the DFG within the SFB/TR 49.

MA 48.4 Thu 10:15 HSZ 101

Auto-oscillations in YIG/Pt nanostructures driven by the spin Seebeck effect — •Viktor Lauer[1], Micheal Schneider[1], Thomas Meyer[1], Philipp Pirro[1], Frank Heussner[1], Carsten Dubs[2], Bert Lägel[1], Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

We report on experimental investigations of magnetization auto-oscillations excitated in the YIG layer of a YIG/Pt nanowire driven by the spin Seebeck effect (SSE). DC current pulses applied to the nanowire result in Joule heating of the Pt layer, and lead to the formation of a thermal gradient across the YIG/Pt interface. The thermal gradient gives rise to a SSE-induced spin current injected into the YIG layer which exerts an anti-damping torque on the magnetization, and, eventually, excites magnetization precession. Time-resolved Brillouin light scattering microscopy is used to investigate the temporal evolution and spatial distribution of the excited magnetization dynamics in the nanowire. These findings are of interest since they suggest the generation of a coherent precession state from incoherent SSE-injected magnons and reveal a realization of microwave sources at room temperature. This research has been supported by: EU-FET Grant InSpin 612759, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1, and SE 1771/4-2 within SPP 1538)

MA 48.5 Thu 10:30 HSZ 101

Non-local magnon transport in iron garnet/Pt nanostructures — •Kathrin Ganzhorn[1,2], Tobias Wimmer[1,2], Zhiyong Qiu[3], Stephan Gepraegs[1], Nynke Vlietstra[1], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], Eiji Saitoh[3], and Sebastian T.B. Goennenwein[1,2,4,5] — [1]Walther-Meissner-Institut, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Institute for Materials Research, Tohoku University, Sendai, Japan — [4]Nanosystems Initiative Munich, Munich, Germany — [5]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany

Magnons, the carriers of angular momentum in magnetically ordered systems, are attractive for information transfer and processing. For the realization of corresponding devices, an all-electrical generation and detection of magnons is desirable. Recent experiments in yttrium iron garnet/platinum (YIG/Pt) bilayers show that non-equilibrium magnons can be injected electrically into the insulating YIG by driving a dc charge current through the Pt, via spin scattering mechanisms at the YIG/Pt interface. The magnons propagate through the YIG and are detected as a non-local resistive voltage in a second, electrically isolated Pt strip [1,2]. We study this effect, called magnon-mediated magnetoresistance (MMR), in different iron garnet/Pt systems as a function of the distance between injector and detector, temperature and magnetic field. This work is supported by the DFG via SPP 1538.
[1]L. Cornelissen et al., Nat. Phys. **11**, 1022 (2015) [2]S. T. B. Goennenwein et al., Appl. Phys. Lett. **107**, 172405 (2015)

MA 48.6 Thu 10:45 HSZ 101

Temperature dependent magnon polariton spectroscopy in YIG sphere — •Isabella Boventer[1], Marco Pfirrmann[2], Martin Weides[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz, 55128 Mainz — [2]Institute of Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe

For information technology, the spin based approach is a promising candidate for new applications such as data storage and communication. The collective excitation of a spin ensemble results in a spin wave in the microwave (GHz) regime, termed magnon. Experimentally, we interface magnons with microwave cavities to investigate the dynamics within the magnetic system. The sample is a millimetre sized YIG sphere, placed in the 6.5 GHz bright mode of a reentrant cavity. The magnonic elements are strongly coupled to the photonic resonator, resulting in hybridized magnon-resonator states, called magnon polaritons. We have set up an experimental apparatus for the resonant coupling of spin waves in a magnetic bulk or thin film to either inside a microwave cavity or a coplanar waveguide (CPW) in the strong coupling regime [1,2]. This enables both readout at a fixed frequency or broadband measurements employing ferromagnetic resonance (FMR) and input-output theory for temperatures from 5 K to 300 K. We present temperature dependent spectroscopic measurements of the magnon-polariton states. Features of the strongly coupled such as the coupling strength g and linewidth are discussed. [1] Y. Tabuchi, et al., Phys. Rev. Lett. 113, 083603 (2014) [2] X. Zhang, et al., Phys. Rev. Lett 113, 156401 (2014)

MA 48.7 Thu 11:00 HSZ 101

Study of Thermally Tunable Coupled Magnetic Vortex Oscillators with Lorentz Transmission Electron Microscopy and Differential Phase Contrast Microscopy — •Johannes Wild, Michael Vogel, Felix Schwarzhuber, Bernhard Zimmermann, Christian Back, and Josef Zweck — Universität Regensburg, Deutschland

Magnetic vortex oscillators are an ideal system to study the dynamics of magnetic systems at very small length scales and over a wide frequency range. Their dynamic behavior shows characteristics known from other fundamental physical systems like the harmonic oscillator and is in many aspects well understood. Here we present a study of coupled vortices with Lorentz Transmission Electron Microscopy (LTEM) and Differential Phase Contrast Microcopy (DPC) at zero magnetic field. We show a novel technique to control the interaction of two or more vortex oscillators by directly influencing their resonance frequencies. The resonance frequencies depend on the saturation magnetization M_s of the magnetic material, in this case permalloy and is highly dependent on the temperature. We use Joule heating to electrically manipulate the resonance frequencies and thus are able to control the coupling between two vortex oscillators. We systematically mapped the frequency response of both oscillators for different temperatures.

15 min. break

MA 48.8 Thu 11:30 HSZ 101

Spin-orbit torques in Chern insulators — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spin-orbit torques (SOTs) arise as a result of an applied electric field in systems that combine broken spatial inversion symmetry and spin-orbit coupling. They allow for an efficient magnetization control in single ferromagnetic layers [1] mediated by the current-induced exchange of angular momentum between crystal lattice and magnetization. While previous works focused on SOTs in topologically trivial materials such as magnetic bilayers, the nature and magnitude of this phenomenon in insulators with globally nontrivial topology in reciprocal space was hardly addressed. Here, employing density functional theory and model calculations, we make contact with the field of Chern and topological insulators by investigating the SOT and Dzyaloshinskii-Moriya interaction (DMI) in a topologically complex system of magnetically-doped graphene. Both phenomena reveal unique fingerprints of the underlying topology, and we evaluate their interplay with the magnetization direction using higher-dimensional Wannier functions [2]. Remarkably, despite the absence of a longitudinal current, we predict that the magnitude of SOT and DMI in this family of Chern insulators is comparable to that observed in conventional magnetic metallic materials, which opens new vistas for dissipationless electric magnetization control.

[1] I. M. Miron *et al.*, Nature **476**, 189 (2011).
[2] J.-P. Hanke *et al.*, Phys. Rev. B **91**, 184413 (2015).

MA 48.9 Thu 11:45 HSZ 101

Phase control in magnetic oscillators — •Michael Vogel[1], Johannes Wild[1], Felix Schwarzhuber[1], Bernhard Zimmermann[1], Claudia Mewes[2], Tim Mewes[2], Josef Zweck[1], and Christian H. Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [2]MINT Center / Depeartment of Physics and Astronomy, University of Alabama, Tuscaloosa, AL, USA

Magnetic vortex oscillators coupled via their stray fields [K. Yu. Guslienko, et al. PRB 65, 024414 (2001)] are possible building blocks for high frequency logical networks with scalable dynamics and geometries. For information processing in such networks phase control is crucial. Here we present a novel technique to control the phase of two such oscillators by manipulating the saturation magnetization in one of them by Joule heating. This is demonstrated by high resolution, time resolved STXM measurements performed at the MAXYMUS beamline at Bessy II (Berlin, Germany).

MA 48.10 Thu 12:00 HSZ 101

Spin Hall magnetoresistance up to the THz regime: Signal magnification with spin-waves excitations — •Filipe Souza Mendes Guimarães[1], Manuel dos Santos Dias[1], Juba Bouaziz[1], Antonio Tavares da Costa[2], Roberto Bechara Muniz[2], and Samir Lounis[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Universidade Federal Fluminense, Niterói, Brazil

Spin-orbit-related effects offer the utmost standard of reading and writing information in magnetic units for future devices. These phenomena rely not only on the static orientation of the magnetization but also on its dynamics to achieve fast switchings that can reach the Terahertz regime.[1] In this work, we demonstrate that dynamical charge and spin pumping mechanisms can greatly magnify or dwindle the currents flowing through the system, influencing all kinds of magnetoresistive effects and also Hall currents. In contrast to the static counter-parts, the dynamical signals can be modified by a few to hundreds percents, which leads to immediate implications for device concepts in the THz range. We show, in Co/Pt and Fe/W bilayers, that the variation on the amplitude of these ac-currents can reach up to two orders of magnitude and also affect dc and second harmonic signals. We further show that, by exploring the resonance of the system, dynamical spin Hall angles can non-trivially change sign and be significantly boosted by over 1000%, reaching giant values that are comparable to the dc ones obtained in high resistivity phase of Ta and W.
[1] F. S. M. Guimarães et al., Phys. Rev. B 92, 220410(R) (2015).

MA 48.11 Thu 12:15 HSZ 101

Negative differential conductance in atomic-scale nano-antiferromagnets — •Steffen Rolf-Pissarczyk[1,2], Shichao Yan[1,2], Luigi Malavolti[1,2], Jacob Burgess[1,2], Gregory McMurtrie[1,2], and Sebastian Loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart, Germany

Negative differential conductance (NDC) is a widely applied operation principle in modern electronic devices and it has been observed in different physical systems. The realization of a spin-based NDC effect especially in antiferromagnetic systems may enable new functionality. Here we report the manifestation of a spin-dependent NDC effect through an artificially constructed nano-antiferromagnet in the junction of a spin-polarized scanning tunneling microscope (SP-STM). The NDC occurs due to the occupation of a long-lived excited spin state of the nano-antiferromagnet which reduces the tunneling rate of the spin-polarized tunneling electrons. Applying a master rate equation method based on an effective spin-Hamiltonian provides detailed understanding of the underlying process. This NDC mechanism differs from those previously known as it uses substantially spin selection rather than energy selection in the transport channel.

MA 48.12 Thu 12:30 HSZ 101

Electrically detected magnetic vortex dynamics in Permalloy disks — •Lakshmi Ramasubramanian[1,2], Ciarán Fowley[1], Attila Kákay[1], Oguz Yildirim[1], Patrick Matthes[4], Jürgen Lindner[1], Jürgen Fassbender[3], Sibylle Gemming[1,2], Stefan E. Schulz[2,4], and Alina M. Deac[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Technische Universität Chemnitz, 09126 Chemnitz, Germany — [3]Institute for Physics of Solids, TU Dresden, 01069 Dresden, Germany — [4]Fraunhofer Institute for Electronic Nano Systems, 09126 Chemnitz

The magnetic vortex is a potential candidate for future spintronic devices, like frequency sensors [S. Kasai, et al. PRL 97, 107204 (2006)]

[R. Moriya, et al. Nat. Phys. 4:368 (2008)], spin torque oscillators [V. S. Pribiag, et al. Nat. Phys. 3:498 (2007)], and tunable magnonic crystals [J. Shibata, et al. PRB 67, 224404 (2003)]. The fundamental frequency is determined by the saturation magnetisation, as well as the geometrical confinement of the magnetisation i.e. the diameter and height of a magnetic disk. In this study, Permalloy disks (with radii ranging from 500nm to 4000nm) are patterned and contacted to study the interaction of spin polarized current on the magnetic vortex. The presence of vortex is verified by magneto optic Kerr effect, X-ray photoemission electron microscopy and magnetotransport measurements. The resonance frequency is measured using a lock-in technique based on the anisotropic magnetoresistance effect. Modification of the resonance frequency by ion irradiation will be presented.

MA 48.13 Thu 12:45 HSZ 101

Quantum spin dynamics in a spin-1/2 antiferromagnetic Heisenberg-Ising chain — •Zhe Wang[1,2], Anup Kumar Bera[3], Nazmul Islam[3], Bella Lake[3], Joachim Deisenhofer[2], and Alois Loidl[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Augsburg, Augsburg, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany

Emergent states of matter in quantum magnets are characterized by their elementary magnetic excitations that can be induced and tuned in an external magnetic field. We report on terahertz spectroscopy of elementary excitations in a spin-1/2 Heisenberg-Ising antiferromagnetic chain as a function of temperature and magnetic field. At zero field confined spinon excitations are observed below the Néel temperature [1]. Emergent ferminonic excitations are observed in a transverse magnetic field [2], when the confinement is suppressed and an order-disorder phase transition is induced. In the longitudinal fields, the high-energy string excitations are observed in addition to the low energy spin exciations. These experimental results are understood by comparison to precise calculation of dynamic structure factors by the method of infinite time evolving block decimation and using Bethe ansatz for the transverse and longitudinal fields, respectively.

In collaboration with Hans Engelkamp, Papori Gogoi, Dmytro Kamenskyi, Michael Schmidt, Nanlin Wang, Congjun Wu, Jianda Wu, Shenglong Xu, Wang Yang.

[1]Zhe Wang et al. Phys. Rev. B 91, 140404(R) (2015). [2]Zhe Wang et al. Phys. Rev. B 94, 125130 (2016).

MA 48.14 Thu 13:00 HSZ 101

Quasi-one dimensional spin chains and unconventional magnetic excitations in $YbAlO_3$ — •Stanislav Nikitin[1], Liusuo Wu[2], Leonid Vasylechko[3], and Andrey Podlesnyak[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, 01187, Germany — [2]Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA — [3]Lviv Polytechnic National University, Lviv, 79000, Ukraine

The low-energy spin dynamics of Yb^{3+} in $YbAlO_3$ have been studied using inelastic neutron scattering. We observe that Yb^{3+} moments form weakly coupled spin chains running along the c-axis without any significant magnetic interactions within the ab plane. CEF effect leads to large splitting of the Yb^{3+} multiplet $J = \frac{7}{2}$ and the magnetic properties at low temperatures are always dominated by the lowest-energy doublet, which can be described as pseudo spin $S = \frac{1}{2}$, and the effective Lange g-factor. Excitation spectrum of $YbAlO_3$ above the ordering temperature $T_N = 0.9\ K$, precisely represents a gapless multispinon continuum as was predicted for a $S = \frac{1}{2}$ Heisenberg chain. Below T_N the gap $\Delta = 0.3$ meV appears and the spectrum splits into the single-particle mode and two-particle continuum. Of particular relevance for the present results are also our previous investigations of $YbFeO_3$. In this compound Yb^{3+} moments forms similar magnetic chains but magnetic excitations are highly modified by a strong Fe-Yb interaction. Our results represent a rather rare case of quantum spin dynamics in 4f based systems and provide an experimental basis for future studies of low-dimensional magnets.

MA 49: Surface Magnetism 2 (Joint Session with O)

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

MA 49.1 Thu 9:30 HSZ 401

First-principles ground state charge currents and orbital magnetic moments in magnetic nanostructures — •Sascha Brinker, Manuel dos Santos Dias, Filipe Souza Mendes Guimarães, and Samir Lounis — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich

The classical definition of the orbital magnetic moment (OMM) using the ground state charge current is well-defined for finite systems, while for periodic systems the modern theory of orbital magnetization applies [1]. In this work we consider the intermediate case: magnetic nanostructures on surfaces from first-principles. We outline our density functional theory implementation in the Korringa-Kohn-Rostoker (KKR) Green function method, in a real-space approach. As an application we consider transition metal adatoms and clusters on a Pt(111) surface, and their ground state charge current distributions. We then find two contributions to the OMM – a local contribution corresponding to the swirling charge currents around each atom and a contribution related to the net currents flowing between atoms. Two mechanisms lifting the orbital degeneracy are investigated — spin-orbit coupling and non-collinear magnetic structures with finite scalar spin chirality.

Work funded by the HGF-YIG Programme VH-NG-717 (FunSiLab) and the ERC-consolidator grant DYNASORE.
[1] T. Thonhauser, Int. J. Mod. Phys. B **25**, 1429 (2011)

MA 49.2 Thu 9:45 HSZ 401

Quantum interference effects in molecular spin hybrids — •Taner Esat[1], Rico Friedrich[2], Frank Matthes[3], Vasile Caciuc[2], Nicolae Atodiresei[2], Stefan Blügel[2], Daniel E. Bürgler[3], F. Stefan Tautz[1], and Claus M. Schneider[3] — [1]Peter Grünberg Institute (PGI-3), FZ Jülich, Germany — [2]Peter Grünberg Institute (PGI-1) and Institute for Advanced Simulation (IAS-1), FZ Jülich — [3]Peter Grünberg Institute (PGI-6), FZ Jülich

Magnetism of molecules is in the focus of intense research, because it could lead to new spin-based electronic devices. An interesting approach is to tailor hybrid molecular magnets from a non-magnetic molecule by spin-dependent hybridization with a ferromagnetic building block, since such hybrid systems promise unique magnetic functionalities.

In this work we have studied by means of low-temperature scanning tunneling microscopy (STM) and spectroscopy (STS) single molecular spin hybrids formed upon chemisorbing a polycyclic aromatic hydrocarbon molecule on Co(111) nanoislands. The spin-dependent hybridization between the Co d-states and the π-orbitals of the molecule leads to a spin-imbalanced electronic structure of the chemisorbed organic molecule. Spin-sensitive measurements reveal that the spin polarization shows intramolecular variations among the different aromatic rings in spite of the highly symmetric adsorption geometry. We rather relate the varying degree of spin polarization to the superposition of the spin polarization of the molecule and the spatially modulated spin polarization of the Co(111) sp surface state.

MA 49.3 Thu 10:00 HSZ 401

Magnetic properties of the ultrathin Co films grown on the curved Ni(111) and Pd(111) single crystals — •Maxim Ilyn[1,2], Laura Fernandez[2], Ana Magaña[1,3], Philippe Ohresser[4], Enrique Ortega[1,2,3], and Frederik Schiller[1] — [1]Materials Physics Center CSIC-UPV/EHU, San Sebastian, Spain — [2]Donostia International Physics Center, San Sebastian, Spain — [3]Department of Applied Physics, University of Basque Country, Bilbao, Spain — [4]Synchrotron SOLEIL, LOrme des Merisiers, France

We investigated the effect of stress and coordination on the magnetic properties of Co nanostructures. The feature of the work is a use of the curved Pd and Ni single crystals as the substrates for the epitaxial growth of Co. The (111) face of these crystals was polished in a shallow cylindrical shape to expose gradually different vicinal surfaces with misorientation +/- 15 degrees towards [11-2] direction. Microscopically these surfaces consist of atomically flat terraces with (111) orientation separated by steps. Average terrace width changes along the curvature from few hundreds nm to 1-2 nm at the edge of the crystal.

In the curved crystals surface stress relaxes gradually with decreasing of the terrace allowing for the variable lattice mismatch between the substrate and the overlayer. Furthermore, atomic steps block diffusion of the adsorbed atoms between the terraces and being the preferential nucleation places change the morphology of the Co nanostructures from 2D islands in the big terraces to 1D atomic chains in the small ones. Our STM and XMCD data show variation of the growth mode and magnetic properties as a function of Co coverage and miscut angle.

MA 49.4 Thu 10:15 HSZ 401

towards non-perturbative reading of atomic spin states with STM — •Luigi Malavolti[1,2], Steffen Rolf-Pissarczyk[1,2], Shichao Yan[1,2], Jacob Burgess[1,2], Gregory McMurtrie[1,2], and Sebastian Loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Deutschland — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Deutschland — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart, Deutschland

Scanning tunneling microscopy (STM) has proven to be an essential tool for the investigation of magnetic phenomena at the atomic scale [1]. By using an STM it is possible to encode, and read information, in the spin state of nano-objects [2]. However, reading the spin state without erasing the information entails fundamental problems due to the quantum nature of the process [3]. This is related to the perturbations introduced by the STM reading: the proximity effect of the tip, the presence of electric field and the tunneling electrons-spin system interaction. Here, we use the high magnetic sensitivity of an atomic scale sensor to read the state of a nearby nano-antiferromagnet (nano-AF). The sensor detects small changes in the local magnetic environment induced by the presence of the nano-AF and transduces them into conductivity changes. This remote reading scheme removes the tip from the nano-AF and effectively mitigates the perturbation, allowing spin state read-out that is five times less invasive than direct inspection.

[1] R. Wiesendanger, Rev. Mod. Phys. 81, 1495 (2009). [2] S. Loth, et al., Science 335, 196 (2012). [3] J.-P. Gauyacq, et al., Phys. Rev. Lett. 110, 87201 (2013).

MA 49.5 Thu 10:30 HSZ 401

Interplay of magnetic coupling and anisotropy of $Ho_3N@C_{80}$ endohedral fullerenes on ferromagnetic substrates — •Matthias Bernien[1], Fabian Nickel[1], Jorge Miguel[1], Lucas M. Arruda[1], Lalminthang Kipgen[1], Norman Blümel[1], Dennis Krüger[1], Andrew J. Britton[1], Enrico Schierle[2], Eugen Weschke[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin

Magnetic endohedral fullerenes are promising candidates for a future molecular spintronics provided one can gain external control over their encapsulated magnetic moments. In $Ho_3N@C_{80}$ three Ho ions are coupled together with a non-collinear alignment of their magnetic moments. Each of the Ho^{3+} ions has a magnetic moment of $10\,\mu_B$ and strong magnetic anisotropy. We use field- and angle-dependent X-ray absorption and X-ray magnetic circular dichroism measurements at a temperature of $T = 4.5$ K and an applied magnetic field up to $B = 6$ T to investigate the magnetic properties of submonolayers of $Ho_3N@C_{80}$ adsorbed on ferromagnetic Ni and Co films. We find that the net moment of $Ho_3N@C_{80}$ couples ferromagnetically to Ni but antiferromagnetically to Co substrates. Both of these couplings to the substrate can be explained by an indirect exchange mechanism mediated by the carbon cage.

Financial support by the DFG (Sfb 658) is gratefully acknowledged.

15 min. break

MA 49.6 Thu 11:00 HSZ 401

Control of helical spin order in Fe nanoislands — •Jeison A. Fischer, Leonid Sandratskii, Dirk Sander, and Stuart Parkin — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany.

An exchange driven helical spin order has been revealed for Fe bilayer islands on Cu(111 [1]. The driving force for the existence of the spin helix with a period of 1.28 nm has been attributed to the competition between ferro- and antiferromagnetic interactions due to the reduced dimensionality of the Fe bilayer islands [1]. Mechanisms to control the non-collinear spin order via lateral confinement with ferromagnet and vacuum interfaces has been demonstrated [2]. Here we report an alternative form to control the magnetic spin order in Fe nanoislands by changing the Fe thickness. Spin-polarized scanning tunneling microscopy and spectroscopy reveals a magnetic stripe phase with a period of 2.3 nm in trilayer Fe nanoislands on Cu(111) [3]. The change in period represents an increase of 80% from bilayer to trilayer systems. Together with theoretical insights, we discuss our finding in view of the role of the layerwise dependence of the exchange interactions acting in the system.

[1] S.-H. Phark, J.A. Fischer, M. Corbetta, D. Sander, K. Nakamura, J. Kirschner, Nat. Commun. 5:5183 doi:10.1038/ncomms6183 (2014).
[2] J.A. Fischer, L.M. Sandratskii, S.-H. Phark, S. Ouazi, A. A. Pasa, D. Sander, S.S.P. Parkin, Nat. Commun. 7, 13000 doi: 10.1038/ncomms13000 (2016).
[3] A. Biedermann, W. Rupp, M. Schmid, P. Varga, Phys. Rev. B 73, 165418 (2006).

MA 49.7 Thu 11:15 HSZ 401

Surface orbitronics from the orbital Rashba physics — •Dongwook Go[1,2], Jan-Philipp Hanke[1], Patrick M. Buhl[1], Frank Freimuth[1], Gustav Bihlmayer[1], Hyun-Woo Lee[2], Yuriy Mokrousov[1], and Stefan Blügel[1] — [1]Institute for Advanced Simulation and Peter Grünberg Institut, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Department of Physics, Pohang University of Science and Technology, 37673 Pohang, Korea

As the inversion symmetry is broken at a surface, spin-orbit interaction gives rise to spin-dependent energy shifts − a phenomenon which is known as the spin Rashba effect. Recently, it has been recognized that an orbital counterpart of the spin Rashba effect − the orbital Rashba effect − can be realized at surfaces even without spin-orbit coupling. Here, we propose a mechanism for the orbital Rashba effect based on *sp* orbital hybridization, which ultimately leads to the electric polarization of surface states. For an experimentally well-studied system of $BiAg_2$ monolayer, as a proof of principle, we show from first principles that this effect leads to chiral orbital textures in **k**-space. In predicting the magnitude of the orbital moment arising from the orbital Rashba effect, we demonstrate the crucial role played by the Berry phase theory for the magnitude and variation of the orbital textures. As a result, we predict a pronounced manifestation of various orbital effects at surfaces, and proclaim the orbital Rashba effect to be a key platform for surface orbitronics.

[1] arXiv:1611.04674.

MA 49.8 Thu 11:30 HSZ 401

Chiral spin coupling across the interface of Fe/W(110) monolayer - double layer coverages — •Anika Schlenhoff, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Recently, various complex magnetic spin structures in metallic thin film systems arising from the interplay of exchange, anisotropy and Dzyaloshinskii-Moriya (DM) interaction have been discovered. For example, the Fe double layer (DL) on W(110) exhibits an inhomogeneous right-rotating cycloidal spin spiral with magnetic domains separated by chiral domain walls [1]. On the Fe monolayer (ML) on W(110) in-plane magnetized domains have been observed [2], but the domain wall chirality has not been investigated yet.

Here, we present spin-polarized scanning tunneling microscopy experiments on combined ML and DL of Fe/W(110). In the ML, adjacent domain walls show a unique rotational sense, indicating an inhomogeneous spin spiral. At the interface between the ML and the DL a deformation of the magnetic domain pattern of the DL is found. Our observations indicate a chiral magnetic coupling of the DL to the ML and a DM vector at the ML - DL interface being perpendicular to the surface.

[1] S. Meckler *et al.*, Phys. Rev. Lett. **103**, 157201 (2009).
[2] M. Pratzer *et al.*, Phys. Rev. Lett. **87**, 127201 (2001).

MA 49.9 Thu 11:45 HSZ 401

All-electrochemical-approach towards voltage-tunable nanomagnets — •Kenny Duschek[1], Andreas Petr[1], Margitta Uhlemann[1], Veronika Hähnel[1], Kornelius Nielsch[1,2], and Karin Leistner[1] — [1]Leibniz-Institute for Solid State and Materials Research, Dresden, Germany — [2]TU Dresden, Germany

Electric field control of magnetism in thin metal/metal oxide nanostructures offers new energy-saving opportunities for the development of microelectromechanical systems, microfluidics and spintronics. Recently, it was shown that large changes in magnetism can be realized by exploiting magneto-ionic effects [1, 2]. In previous studies we obtained large changes of the saturation magnetization in sputter deposited thin iron films by using them as an electrode in an aqueous electrolyte containing 1 M KOH [2]. Changes were achieved by reversibly switching the oxidation state of a 1.5 nm Fe reaction layer. Much larger effects can be obtained by increasing the surface-to-volume ratio of the magnetic nanostructures. Here we demonstrate an all-electrochemical-approach where the magnetism of an electrodeposited nanogranular iron film can be switched almost on and off reversibly. The effects were proved by in situ measurements of the anomalous Hall effect and the ferromagnetic resonance.

[1] U. Bauer, S. Emori and G. S. D. Beach, Nature Nanotechnology 8 (2013) 411-416; [2] K. Duschek, D. Pohl, S. Fähler, K. Nielsch and K. Leistner, APL Materials 4 (2016) 032301-1 - 032301-10

MA 49.10 Thu 12:00 HSZ 401

Purely Antiferromagnetic Magnetoelectric RAM — •Tobias Kosub[1], Martin Kopte[1], Patrick Appel[2], Brendan Shields[2], Patrick Maletinsky[2], René Hübner[1], Jürgen Fassbender[1], Oliver G. Schmidt[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]University of Basel, Basel, Switzerland — [3]IFW Dresden e.V., Dresden, Germany

Magnetic RAM schemes employing magnetoelectric coupling to write binary information promise outstanding energy efficiency [1]. We propose and demonstrate [2] a purely antiferromagnetic magnetoelectric RAM (AF-MERAM) that offers a remarkable 50-fold reduction of the writing threshold compared to ferromagnet-based counterparts and is robust in magnetic fields.

Using the magnetoelectric antiferromagnet Cr_2O_3, we demonstrate reliable operation at room temperature. The antiferromagnetic state is written via gate voltage pulses and is read out all-electrically via Zero-Offset Hall [3]. Based on our prototypes of these novel AF-MERAM elements, we construct a comprehensive model of the magnetoelectric selection mechanism in thin films of magnetoelectric antiferromagnets. We identify that growth induced effects lead to emergent ferrimagnetism, which is detrimental to the robustness of the storage. After pinpointing lattice misfit as the likely origin, we provide routes to enhance or mitigate this emergent ferrimagnetism as desired.

[1] F. Matsukura et al., *Nature Nano.* **10** 209 (2015).
[2] T. Kosub et al., *Nature Commun.* accepted (2016).
[3] T. Kosub et al., *Phys. Rev. Lett.* **115** 097201 (2015).

MA 49.11 Thu 12:15 HSZ 401

Current-induced switching and magnetic relaxation in antiferromagnetic memory devices — •Sonka Reimers[1,2], Carl Andrews[1], Peter Wadley[1], Richard P Campion[1], Kevin W Edmonds[1], Andrew W Rushforth[1], Bryan L Gallagher[1], and Vasily Moshnyaga[2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]I. Physical Institute, Georg-August-Universität, 37077 Göttingen, Germany

To date antiferromagnets (AFs) play only a passive role in spintronic applications. Manipulating and measuring the magnetic state is more difficult than in ferromagnets (FM). On the other hand, purely AF-based devices offer several advantages compared to their FM counterparts including robustness against electric and magnetic perturbations, and ultrafast spin dynamics. It has recently been demonstrated that the local magnetic moment can be switched between stable configurations in biaxial AF CuMnAs thin film devices using electrical current pulses [1].

Future memory applications require a thorough understanding of the magnetic relaxation processes following a current pulse. Experimentally we analyse the dynamics by measuring the time-dependence of the anisotropic magnetoresistance (AMR). We examine the data regarding their information on the magnetic anisotropy of the sample, which may be modified by an externally applied strain, offering an important parameter for controlling the stability of the AF state.

References: [1] P. Wadley et al. "Electrical switching of an antiferromagnet". In: Science 351, 587 (2016)

MA 50: Spincaloric Transport (jointly with TT)

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

MA 50.1 Thu 9:30 HSZ 403

Tunnel magneto-Seebeck effect in $MgAl_2O_4$ based magnetic tunnel junctions — •Torsten Huebner[1], Alexander Boehnke[1], Ulrike Martens[2], Andy Thomas[3], Günter Reiss[1], Markus Münzenberg[2], and Timo Kuschel[1,4] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]IFP, Greifswald University, Germany — [3]IMW, IFW Dresden, Germany — [4]University of Groningen, The Netherlands

The tunnel magneto-Seebeck (TMS) effect describes the changing Seebeck coefficient of a magnetic tunnel junction (MTJ) depending on the relative magnetization alignment of its ferromagnetic electrodes. This effect has been measured in several material systems and with different experimental methods [1-4]. In our study, we focus on MTJs with $MgAl_2O_4$ (MAO) barrier, because of its theoretical advantages in comparison to MgO [5,6]. We find a distinct maximum of the TMS effect at a nominal barrier thickness of 2.6 nm, almost doubling the effect ratio measured at standard barrier thicknesses of (1.8-2.0) nm.

[1] Walter et al., Nat. Mater. 10, 742 (2011)
[2] Liebing et al., Phys. Rev. Lett. 107, 177201 (2011)
[3] Boehnke et al., Rev. Sci. Instrum. 84, 063905 (2013)
[4] Huebner et al., Phys. Rev. B 93, 224433 (2016)
[5] Zhang et al., Appl. Phys. Lett. 100, 222401 (2012)
[6] Miura et al., Phys. Rev. B 86, 024426 (2012)

MA 50.2 Thu 9:45 HSZ 403

Quantitative disentanglement of spin Seebeck, intrinsic anomalous Nernst, and proximity-induced anomalous Nernst effect in NM/FM bilayers — •Panagiota Bougiatioti[1], Christoph Klewe[1,2], Daniel Meier[1], Orestis Manos[1], Olga Kuschel[3], Joachim Wollschläger[3], Laurence Bouchenoire[4,5], Simon D. Brown[4,5], Jan-Michael Schmalhorst[1], Günter Reiss[1], and Timo Kuschel[1,6] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]ALS, Berkeley, California, USA — [3]Fachbereich Physik, Universität Osnabrück, Germany — [4]XMaS, ESRF, Grenoble, France — [5]University of Liverpool, UK — [6]University of Groningen, The Netherlands

In this project, we investigate thermal transport phenomena by separating the anomalous Nernst effect (ANE) contribution (intrinsic and proximity-induced) from the spin Seebeck effect (SSE) voltage on sputter-deposited $Pt/NiFe_2O_{4-x}$ samples. On one hand, we observe a distinct increase of the SSE with the increase of the bandgap energy and the decrease of conductivity, whereas the ANE decreases. On the other hand, a proximity-induced ANE could only be identified in the metallic $Pt/Ni_{33}Fe_{67}$ bilayer. This was verified by the investigation of static magnetic proximity effects via x-ray resonant magnetic reflectivity [1-3]. Further, we determined a maximum moment of 0.48 μ_B per spin-polarized Pt atom in the $Pt/Ni_{33}Fe_{67}$ bilayer.

MA 50.3 Thu 10:00 HSZ 403

Magneto-Seebeck Tunneling Across a Vacuum Barrier — •Cody Friesen, Hermann Osterhage, and Stefan Krause — Department of Physics, University of Hamburg, Jungiusstr. 11A, 20355 Hamburg, Germany

The tunneling magneto-Seebeck effect has been intensively studied both for its potential applications in e.g. waste heat recycling in electronics, and for the insights it can provide into fundamental solid state phenomena [1]. Previously, spin-resolved measurements have been performed using planar magnetic tunneling junctions [2], which limits the achievable spatial resolution.

We have investigated (magneto-)Seebeck tunneling across a vacuum barrier using spin-polarized scanning tunneling microscopy (SP-STM) [4], at low temperatures ($T = 50\,\mathrm{K}$) and UHV conditions. A 15 mW fiber-coupled diode laser was used to heat only the magnetic STM tip, creating a controllable temperature differential across the junction. With this approach the contribution of different surfaces to magneto-Seebeck tunneling has been probed on the Fe/W(110) monolayer system. The first laterally resolved experimental results will be shown and discussed in terms of tunneling thermovoltage and associated magneto-

Seebeck coefficients.
[1] G. Bauer *et al.*, Nat. Mater. **11**, 5 (2012).
[2] M. Walter *et al.*, Nat Mater **10**, 10 (2011).
[3] R. Wiesendanger, Rev. Mod. Phys. **81**, 4 (2009).

MA 50.4 Thu 10:15 HSZ 403

Interface dependent magnon mode coupling in insulating ferrimagnets — •Joel Cramer[1,2], Er-Jia Guo[1,3], Andreas Kehlberger[1], Gerhard Jakob[1], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, 37830 TN, USA

One of the contemporary challenges of magnon spintronics is the profound understanding of magnon mode dependent transport and interface transmission. To approach this problem, we present temperature dependent spin Seebeck (SSE) measurements in uncompensated (yttrium iron garnet (YIG) [1]) and compensated (e.g. gadolinium iron garnet (GdIG) [2]) insulating ferrimagnets. In YIG, a giant enhancement of the SSE amplitude is observed at low temperatures. Despite the bulk origin of the spin current generation, the temperature dependence varies with the used heavy metal (HM) detection layer. Systematic studies including transmission electron microscopy (TEM) reveal that this effect is due to the altered atomistic composition of YIG at the interface. In compensated ferrimagnets, the opposite contribution of distinct magnon modes leads to a sign change of the spin current at low temperatures [3]. We show that different HM layers as well as a modified GdIG surface morphology result in varied interface couplings of these modes, expressed by a temperature shift of the sign change.
[1] Guo et al., Phys. Rev. X 3, 031012 (2016) [2] Cramer et al., (under review) [3] Geprägs et al., Nature Comm. 7, 10452 (2016)

MA 50.5 Thu 10:30 HSZ 403

Quantitative disentanglement of spin Seebeck, intrinsic anomalous Nernst, and proximity-induced anomalous Nernst effect in NM/FM bilayers — •Panagiota Bougiatioti[1], Christoph Klewe[1,2], Daniel Meier[1], Orestis Manos[1], Olga Kuschel[3], Joachim Wollschläger[3], Laurence Bouchenoire[4,5], Simon D. Brown[4,5], Jan-Michael Schmalhorst[1], Günter Reiss[1], and Timo Kuschel[1,6] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]ALS, Berkeley, California, USA — [3]Fachbereich Physik, Universität Osnabrück, Germany — [4]XMaS, ESRF, Grenoble, France — [5]University of Liverpool, UK — [6]University of Groningen, The Netherlands

In this project, we investigate thermal transport phenomena by separating the anomalous Nernst effect (ANE) contribution (intrinsic and proximity-induced) from the spin Seebeck effect (SSE) voltage on sputter-deposited Pt/$NiFe_2O_{4-x}$ samples. On one hand, we observe a distinct increase of the SSE with the increase of the bandgap energy and the decrease of conductivity, whereas the ANE decreases. On the other hand, a proximity-induced ANE could only be identified in the metallic Pt/$Ni_{33}Fe_{67}$ bilayer. This was verified by the investigation of static magnetic proximity effects via x-ray resonant magnetic reflectivity [1-3]. Further, we determined a maximum moment of 0.48 μ_B per spin-polarized Pt atom in the Pt/$Ni_{33}Fe_{67}$ bilayer.
[1] T. Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)
[2] T. Kuschel et al., IEEE Trans. Magn. 52, 4500104 (2016)
[3] C. Klewe et al., Phys. Rev. B 93, 214440 (2016)

15 min. break.

MA 50.6 Thu 11:00 HSZ 403

Pumping laser excited spins through MgO barriers — •Ulrike Martens[1], Jakob Walowski[1], Thomas Schumann[1], Maria Mansurova[1], Alexander Boehnke[2], Torsten Huebner[2], Guenter Reiss[2], Andy Thomas[3], and Markus Muenzenberg[1] — [1]Institut für Physik, EMAU Greifswald, Germany — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Institute for Metallic Materials, IFW Dresden, Germany

We present a study of the tunnel magneto-Seebeck (TMS) effect in MgO based magnetic tunnel junctions (MTJs). The electrodes consist of CoFeB with in-plane magnetic anisotropy. The temperature gradients which generate a voltage across the MTJs layer stack are created using laser heating. Using this method, the temperature can be controlled on the micrometer length scale: here, we investigate, how both, the TMS voltage and the TMS effect, depend on the size, position and intensity of the applied laser spot. For this study, a large variety of different temperature distributions was created across the junction. We recorded two-dimensional maps of voltages generated by heating in dependence of the laser spot position and the corresponding calculated TMS values. The voltages change in value and sign, from large positive values when heating the MTJ directly in the centre to small values when heating the junction on the edges and even small negative values when heating the sample away from the junction. Those zero crossings lead to very high calculated TMS ratios.
Funding by DFG SPP 1538 is acknowledged

MA 50.7 Thu 11:15 HSZ 403

Thermally Induced Spin Transfer Torque on MgO-based magnetic tunnel junctions using microresonators — •Hamza Cansever[1,2], Ciaran Fowley[1], Rysard Narkovicz[1], Ewa Kowalska[1,2], Yuriy Aleksandrov[2], Oguz Yildirim[1], Aleksandra Titova[1,2], Kilian Lenz[1], Jürgen Lindner[1], Jürgen Fassbende[1], and Alina M. Deac[1] — [1]Helmholtz Zentrum Dresden Rossendorf Institute of Ion Beam Physics and Materials Research — [2]TU Dresden Institute of Solid State Physics

Magnetic tunnel junctions have been commonly used in spintronics applications, such as magnetic random access memory (M-RAM), spin transfer torque RAM (STT-RAM) and hard disc drive (HDD) because of high storage capacity. A spin polarized current flowing through a ferromagnetic layer can exert spin-transfer-torque (STT) on the local magnetization. When we apply thermal gradient across the junction we can induce what is called thermal spin transfer torque (T-STT). In this study, the microresonator FMR technique is used in order to analyze how the ferromagnetic resonance signal corresponding to the free layer of an in-plane MgO-based tunnel junction device is modified in the presence of a temperature gradients across the barrier. Details of resonator fabrication and preliminary measurements are presented. This work is supported by DFG-SPP1538.

MA 50.8 Thu 11:30 HSZ 403

Quantitative separation of the anisotropic magnetothermopower and planar Nernst effect by the rotation of an in-plane thermal gradient — •Oliver Reimer[1], Daniel Meier[1], Michel Bovender[1], Lars Helmich[1], Jan-Oliver Dreessen[1], Jan Krieft[1], Jan-Michael Schmalhorst[1], Andreas Hueutten[1], Guenter Reiss[1], and Timo Kuschel[1,2] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]University of Groningen, The Netherlands

A ferromagnet exposed to a thermal gradient ∇T in an external magnetic field $\vec{H}$ generates a spin current parallel to ∇T (longitudinal spin Seebeck effect [1]) which can be detected in materials with high spin orbit coupling (e.g. Pt) by the inverse spin Hall effect. Up to now, all spin caloric experiments employ a spatially fixed ∇T. The use of a recently reported new experimental setup allows the rotation of an in-plane ∇T [2]. In this talk, it will be shown, that combined with a rotatable external magnetic field, the rotation of ∇T reveals a phase shift of the magnetothermopower angular dependence with respect to the magnetization direction in a permalloy thin film. Supported by a theoretical model this phase shift allows to unambiguously separate the Seebeck voltage, the anisotropic magnetothermopower and the planar Nernst effect within one experiment.
[1] K. Uchida et al., Appl. Phys. Lett. 97, 172505 (2010)
[2] O. Reimer et al., arXiv: 1609.08822 (2016)

MA 50.9 Thu 11:45 HSZ 403

Insights into the spin-orbit coupling mediated thermoelectric properties of half metallic full Heusler alloys — •Voicu Popescu and Peter Kratzer — Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany

We have performed first-principles investigations on the native defects in the half-metallic ferromagnetic full Heusler alloys Co$_2$TiZ (Z one of the group IV elements Si, Ge, Sn). We modelled the defects as dilute alloys, and treated them in the coherent potential approximation within the framework of the full potential spin-polarized relativistic Korringa-Kohn-Rostoker Green function method. The self-consistent potentials determined this way were used to calculate the residual resistivity via the Kubo-Greenwood formula and, based on its energy dependence, the Seebeck coefficient of the systems. The latter is shown to depend significantly on the type of defect, variations that are related to subtle changes in the electronic structure around the half-metallic gap induced by the spin-orbit coupling. Amongst the different investigated intrinsic defects, two of them exhibit a negative Seebeck coefficient, in good agreement with the available experimental data.

MA 51: Topological Insulators I (joined session with TT)

Time: Thursday 9:30–12:45 Location: POT 251

Invited Talk MA 51.1 Thu 9:30 POT 251

Sub-nm probing of Topological insulators and Rashba systems — •Markus Morgenstern — II. Institute of Physics and JARA-FIT, RWTH Aachen, D-52074 Aachen, Germany

Spin-orbit interactions in solids are the key for many anticipated new functionalities ranging from the meanwhile traditional Datta-Das transistor to topological quantum computation using Majorana excitations. Local probes can provide crucial information on this interaction down to the nm scale. Within this talk, I will show how scanning tunneling spectroscopy reveals the presence of topologically protected edge states provided by a spin-orbit induced band inversion of heavy metal graphene [1], how the detrimental fluctuations of the spin-orbit interaction can be probed down to the nm length scale [2], and that ferroelectricity induces Rashba-type spin-orbit interaction within the bulk of the simple binary material GeTe [3].

[1] C. Pauly et al., Nat. Phys. 11, 338 (2015); ACS Nano 10, 3995 (2016). [2] J. R. Bindel et al., Nat. Phys. 12, 920 (2016). [3] M. Liebmann et al., Adv. Mat. 20, 560 (2016); H. J. Elmers et al., Phys. Rev. B 94, 201403 (2016).

MA 51.2 Thu 10:00 POT 251

2D Topological Insulators: Trends in Chemical Space — •Carlos Mera Acosta[1,2], Christian Carbogno[1], Adalberto Fazzio[2], Luca M. Ghiringhelli[1], and Matthias Scheffler[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [2]Instituto de Física, Universidade de São Paulo, SP, Brazil

2D topological insulators (TI) have attracted considerable scientific interest in recent years [1]. The search for new TIs has often focused on elements with strong spin-orbit coupling (SOC) [2], which can induce the necessary topological transition. In this work, we have computed the topological invariant Z_2 for 200 functionalized honeycomb-lattice systems using our recent Wannier center of charge (WCC) [3] implementation in the FHI-aims electronic structure code. Besides confirming the TI character of well-known materials, e.g., functionalized stanene [1], our study found several other yet unreported TIs. This reveals that also elements with relatively low SOC can form TIs. To analyze the observed trends in chemical space we relate the WCCs to the atomic features of the constituent atoms using a compressed-sensing approach. For this purpose, the LASSO and ℓ_0 minimization of Ref. [4] is extended from learning scalar properties to functions.

This work received funding from The Novel Materials Discovery (NOMAD) Laboratory, a European Centre of Excellence.

[1] Y. Ren, Z. Qiao, and Q. Niu, *RPP* **79**, 6 66501 (2016).
[2] M. Z. Hasan and C. L. Kane, *Rev. Mod. Phys.* **82**, 3045 (2010).
[3] R. Yu, *et al.*, *Phys. Rev. B* **84**, 075119 (2011).
[4] L. M. Ghirighelli, *et al.*, *Phys. Rev. Lett.* **114**, 105503 (2015).

MA 51.3 Thu 10:15 POT 251

Occupied topological surface states in strained α-Sn — Victor Rogalev[1], •Tomáš Rauch[2], Markus Scholz[1], Felix Reis[1], Lenart Dudy[1], Andrzej Fleszar[3], Vladimir Strocov[4], Jürgen Henk[2], Ingrid Mertig[2,5], Jörg Schäfer[1], and Ralph Claessen[1] — [1]Physikalisches Institut und Röntgen Center for Complex Material Systems, Universität Würzburg, 97074 Würzburg, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany — [3]Institut für Theoretische Physik und Astronomie, Universität Würzburg, 97074 Würzburg, Germany — [4]Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen, Switzerland — [5]Max Planck Institute for Microstructure Physics, 06120 Halle (Saale), Germany

Unstrained α-Sn is a semimetal with a non-trivial band ordering at the Γ point of the bulk Brillouin zone: $E(\Gamma_8^+) > E(\Gamma_7^-) > E(\Gamma_7^+)$. Strain in (001) direction lifts the degeneracy of the Γ_8^+ level at the Fermi energy. We demonstrate that compressive strain turns the system into a strong topological insulator, whereas tensile strain causes a transition into the topological Dirac semimetal phase.

I will present the results of calculations carried out along experimental findings obtained by soft X-ray angle-resolved photoemission. I will show that the existence of a previously unknown surface state located in the occupied projected bulk band structure of α-Sn is unveiled by both experimental and theoretical methods. In addition, its topological origin was confirmed by calculating the topological invariants of the bulk bands.

MA 51.4 Thu 10:30 POT 251

Engineering topological phases in crystalline symmetry-protected monolayers — •Chengwang Niu, Patrick M. Buhl, Gustav Bihlmayer, Daniel Wortmann, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The properties that distinguish topological crystalline insulators (TCIs) and topological insulators (TIs) rely on crystalline symmetry and time-reversal symmetry, respectively, which encodes different surface/edge properties. Here, we predict theoretically that TlM, thallium chalcogenide, (M = S and Se) (110) monolayers realize a family of two-dimensional (2D) TCIs characterized by mirror Chern number $\mathcal{C}_M = -2$ with an even number of band inversions. [1] Remarkably, under uniaxial strain ($\approx$ 1%), a topological phase transition between 2D TCI and 2D TI is revealed in TlM. In contrast, for Na_3Bi, the band inversion occur at single k point, thus a coexistence of 2D TI and 2D TCI is obtained. [2] Finally, we show different edge-state behaviors, especially at the time reversal invariant points.

This work was supported by SPP 1666 of the DFG.

[1] C. Niu, P. M. Buhl, G. Bihlmayer, D. Wortmann, S. Blügel, and Y. Mokrousov, Nano Lett. **15**, 6071 (2015).

[2] C. Niu, P. M. Buhl, G. Bihlmayer, D. Wortmann, S. Blügel, and Y. Mokrousov, submitted.

MA 51.5 Thu 10:45 POT 251

Anisotropy of Magneto-Transport on the Surface of Topological Insulators — •Alexey Taskin[1], Henry Legg[2], Fan Yang[1], Andrea Bliesener[1], Satoshi Sasaki[3], Yasushi Kanai[3], Kazuhiko Matsumoto[3], Achim Rosch[2], and Yoichi Ando[1] — [1]Institute of Physics II, University of Cologne — [2]Institute for Theoretical Physics, University of Cologne — [3]Scientific and Industrial Research, Osaka University

Recent advances in MBE growth and microfabrication technique allow to obtain Topological Insulator (TI) systems where the transport is dominated by the surface. Here we report a magneto-transport study of high-quality bulk-insulating $Bi_{2-x}Sb_xTe_3$ thin films, which were fabricated into devices with electrostatic gates on both bottom and top surfaces. For magnetic fields applied parallel to the surface of a TI, we found a clear anisotropy in magnetoresistance and related planar Hall effect that originates from the fundamental property of the surface Dirac fermions, the locking of their spin and momentum. The key signature of anisotropic magnetoresistance is a strong dependence on the gate voltage with a characteristic two-peak structure near the Dirac point. The observed anisotropy is related to a modification of the topological protection of the Dirac electrons against backscattering from impurities in the in-plane magnetic field and provides an example of a controllable time-reversal breaking on the surface of TIs.

Coffee Break

MA 51.6 Thu 11:30 POT 251

Topological insulator - superconductor hybrid devices — •Peter Schüffelgen, Daniel Rosenbach, Michael Schleenvoigt, Tobias W. Schmitt, Martin Lanius, Christian Weyrich, Tristan Heider, Benjamin Bennemann, Stefan Trellenkamp, Elmar Neumann, Gregor Mussler, Thomas Schäpers, and Detlev Grützmacher — Peter Grünberg Institute 9, Forschungszentrum Jülich & JARA-FIT, 52425 Jülich, Germany

3D topological insulators (TIs) possess metallic surface states with a spin-locked momentum. Therefore, in proximity to an s-wave superconductor, Majorana zero modes (MZMs) are predicted to occur at the surface of TIs. We found first signatures of 4π-periodic Josephson supercurrents in our topological Josephson junctions. The TI thin film was grown by means of molecular beam epitaxy on a Si(111) substrate and capped in-situ by a thin layer of aluminum to prevent thin film degradation and to preserve the pristine surface states during ex-situ fabrication. To increase the 4π-periodic contribution we fabricated quasi 1D Josephson junctions on pre-patterned silicon substrates. By covering the Si-111 surface partly with a thin layer of Si3N4/SiO2 we made the topological insulator grow only on the silicon surface. In this way we were able to realize 1D trenches by predefining the MESA structure before MBE growth. To further improve the quality of our hybrid devices we developed a process, which allows to deposit superconducting contacts via stencil lithography. Combining this technique with selective area growth allows to fabricate complex devices in-situ.

MA 51.7 Thu 11:45 POT 251

Ultrafast mid-IR pump, THz probe spectroscopy investigating of the topological insulator BSTS — •Matteo Montagnese, Jingy Zhu, Chris Rheinhoffer, Yoichi Ando, and Paul H. M. van Loosdrecht — II. Physikalishes Institut der Universität zu Köln, Zülpicher str 77, D-25127 Köln

We present ultrafast pump-probe measurements on the topological insulator BSTS. We employed a high-intensity tunable mid-IR pulse (2-10 microns) as a pump, generated by difference-frequency mixing in an optical parametric amplifier to excite the BSTS system below the onset of the bulk optical electronic continuum. Upon excitation, the far-IR (0.1-3 THz) response of the system has been probed by a single-cycle coherent THz pulse, generated by optical rectification of a near-IR pulse. The time-resolved transmittance of the THz spectra have been measured employing optical sampling and time-domain techniques. By tuning the pump energy, the impurity states leading to charge puddle formation and the surface state are selectively populated, with the aim of disentangling their respective contributions to the dynamic optical conductivity.

MA 51.8 Thu 12:00 POT 251

Observation of the Quantum Anomalous Hall Effect depending on structural properties of $(VBiSb)_2Te_3$ layers — •Martin Winnerlein, Steffen Schreyeck, Stefan Grauer, Sabine Rosenberger, Kajetan Fijalkowski, Charles Gould, Karl Brunner, and Laurens W. Molenkamp — Physikalisches Institut, Experimentelle Physik III, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The quantum anomalous Hall effect is observed in thin V-doped $(BiSb)_2Te_3$ layers, a magnetic topological insulator. Thin layers revealing quantization are reproducibly deposited by molecular beam epitaxy at growth conditions effecting a compromise between controlled layer properties and high crystal quality. The influence of Sb content, layer thickness, structural quality, used substrates and cap layers is studied.

The Sb content is the main layer parameter to be optimized in order to approach charge neutrality. The Sb content is reliably determined from the in-plane lattice constant measured by X-ray diffraction even in thin layers. Within a narrow range at about 80% Sb content, the Hall resistivity reveals a maximum at 4 K and quantizes at mK temperatures [1]. Under these conditions thin layers grown on Si(111) or InP(111) and with or without a Te cap layer exhibit quantization. The quantization persists independently from the substrate, cap layer, the limited crystal quality and the degradation of the layer. This proves the robustness of the quantum anomalous Hall effect.

[1] S. Grauer *et al.*, Phys. Rev. B **92**, 201304 (2015).

MA 51.9 Thu 12:15 POT 251

Quantum Hall effect in three-dimensional Bi_2Se_3 single crystals — •Olivio Chiatti[1], Marco Busch[1], Sergio Pezzini[2], Steffen Wiedmann[2], Oliver Rader[3], Lada V. Yashina[4], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]High Field Magnet Laboratory, Radboud University Nijmegen, 6525ED Nijmegen, The Netherlands — [3]Helmholtz-Zentrum-Berlin für Materialien und Energie, 12489 Berlin, Germany — [4]Department of Chemistry, Moscow State University, 119991 Moscow, Russia

Topological insulators present surface (or edge) states of helically spin-polarized Dirac fermions, which are readily identified by spectroscopic methods. However, they are not so easily identified in transport, because they can be masked by bulk states. Bi_2Se_3 is one of the prototype topological insulators, but investigating transport by surface states has been hampered by residual bulk charge carriers. We have investigated nominally undoped, high-quality Bi_2Se_3 single crystals, with bulk electron densities of $n \approx 1.8 \cdot 10^{19}$ cm^{-3} and mobilities of up to $\mu \approx 10^3$ cm^2/Vs. Surface states have been confirmed by ARPES measurements [1]. We have measured magnetotransport between $T = 0.3$ K and $T = 72$ K, for tilted magnetic fields up to $B = 33$ T. We observe both Shubnikov-de Haas (SdH) effect and quantum Hall effect (QHE). The SdH oscillations appear dominated by 3D bulk charge carriers. However, the scaling of the QHE with sample thickness can be interpreted as transport over layered 2D states in the bulk.

[1] Chiatti *et al.*, Sci. Rep. **6**, 27483 (2016)

MA 51.10 Thu 12:30 POT 251

The electronic structure of few-quintuple-layer bismuth selenide from first-principles calculations — •Jae Young Kim and Cheol-Hwan Park — Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea

Topological insulators are materials that behave as insulators in the interior, but have conducting surface states protected by time-reversal symmetry [1]. Bi2Se3, a prototypical example of a three-dimensional topological insulator, is a layered material composed of five-atom layers arranged along the z-direction, known as quintuple layers [2]. In this presentation, we will discuss the results of our first-principles calculations on the electronic properties of few-quintuple-layer Bi2Se3 and their relevance to device applications based on topological insulators.

[1] Hasan, M. Z., & Kane, C. L. (2010). Colloquium: topological insulators. Reviews of Modern Physics, 82(4), 3045.

[2] Zhang, H., Liu, C. X., Qi, X. L., Dai, X., Fang, Z., & Zhang, S. C. (2009). Topological insulators in Bi2Se3, Bi2Te3 and Sb2Te3 with a single Dirac cone on the surface. Nature physics, 5(6), 438-442.

MA 52: Topological Insulators II (joined session with TT)

Time: Thursday 14:45–16:45 Location: POT 251

MA 52.1 Thu 14:45 POT 251

Visualizing the response of Weyl semimetals to Coulomb and magnetic perturbations — •Thomas Bathon[1], Paolo Sessi[1], Yan Sun[2], Florian Glott[1], Zhilin Li[3], Hongxiang Chen[3], Liwei Guo[3], Xialong Chen[3], Markus Schmidt[2], Claudia Felser[2], Binghai Yan[2], and Matthias Bode[1] — [1]Experimentelle Physik II der Universität Würzburg, Würzburg — [2]Max Planck Institute for Chemical Physics of Solids, Dresden — [3]Institute of Physics at the Chinese Academy of Sciences, Peking

Weyl semimetals are a new class of topological materials which led to the emergence of Weyl physics in condensed matter. While photoemission successfully identified Weyl surface states with unique Fermi arcs, their fundamental microscopic properties, such as scattering mechanisms, persistence of spin-coherence, and the reaction to external perturbations, have not been widely investigated so far.
Here, we use TaAs to address these important aspects at the atomic scale by scanning tunneling microscopy and spectroscopy. We deliberately introduce external adatoms to test the response of this class of materials to well-defined Coulomb and magnetic perturbations. We demonstrate that, contrary to topological insulators, they are effectively screened in Weyl semimetals. Our analysis demonstrates that intra- as well as inter-Fermi arc scattering events are strongly suppressed. Additionally, we show that the existence of large parallel segments of spin-split trivial states facing each other makes possible, through scattering, to revert both the propagation direction while simultaneously flipping the spin state, strongly limiting its coherence.

MA 52.2 Thu 15:00 POT 251

Investigation of topological states in proximitized superconducting 2d materials — •Petra Högl, Denis Kochan, Tobias Frank, Martin Gmitra, and Jaroslav Fabian — Insitute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

Recently, the appearance of helical edge states in graphene in transition-metal dichalcogenides has been predicted [1]. The presence of these quantum spin Hall states is a precursor for topological insulators. We theoretically investigate such 2d systems proximitized to a s-wave superconductor. As predicted by Fu and Kane [2] the combination of 2d topological insulators and superconductors can lead to the formation of Majorana states. This work has been supported by

the Int. Doctorate Program Topological Insulators of the Elite Network of Bavaria, DFG SFB 689, GRK 1570, and by the EU Seventh Framework Programme under Grant Agreement No. 604391 Graphene Flagship.

[1] M. Gmitra, D. Kochan, P. Högl, J. Fabian, Phys. Rev. B 93, 155104 (2016)

[2] L. Fu and C. L. Kane, Phys. Rev. B 79, 161408(R) (2009)

MA 52.3 Thu 15:15 POT 251

Tuning Quantum Transport and Interference in Topological Nanowires — •Vincent Sacksteder[1] and Quansheng Wu[2] — [1]W155 Wilson Building, Royal Holloway University of London, Egham Hill, Egham, TW20 0EX, United Kingdom — [2]Theoretical Physics and Station Q Zurich, ETH Zurich, 8093 Zurich, Switzerland

We study the magnetoconductance of topological insulator nanowires in a longitudinal magnetic field, including Aharonov-Bohm, Altshuler-Aronov-Spivak, perfectly conducting channel, and universal conductance fluctuation effects. We show that changing the Fermi energy can tune a wire from from ballistic to diffusive conduction and to localization. In both ballistic and diffusive single wires we find both Aharonov-Bohm and Altshuler-Aronov-Spivak oscillations with similar strengths, accompanied by quite strong universal conductance fluctuations (UCFs), all with amplitudes between 0.3 and 1 conductance quanta. This contrasts strongly with the average behavior of many wires, which shows Aharonov-Bohm oscillations in the ballistic regime and Altshuler-Aronov-Spivak oscillations in the diffusive regime, with both oscillations substantially larger than the conductance fluctuations. We also show that in long wires the perfectly conducting channel is visible at a wide range of energies within the bulk gap. We present typical conductance profiles at several wire lengths, showing that conductance fluctuations can dominate the average signal. Similar behavior will be found in carbon nanotubes.

Coffee Break

MA 52.4 Thu 16:00 POT 251

time-reversal-breaking topological phases in anti-ferromagnetic Sr_2FeOsO_6 films — •Xiao-Yu Dong[1,2], Sudipta Kanungo[3,4], Binghai Yan[2,3], and Chao-Xing Liu[5] — [1]Department of Physics and State Key Laboratory of Low-Dimensional Quantum Physics, Tsinghua University, Beijing 100084, P.R.China — [2]Max-Planck-Institut für Physik komplexer Systeme, 01187, Dresden, Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany — [4]Center for Emergent Matter Science (CEMS), RIKEN, 2-1, Hirosawa, Wako, Saitama 351-0198, Japan — [5]Department of Physics, The Pennsylvania State University, University Park, Pennsylvania 16802-6300, USA

In this work, we studied time-reversal-breaking topological phases as a result of the interplay between anti-ferromagnetism and inverted band structures in anti-ferromagnetic double perovskite transition metal Sr_2FeOsO_6 films. By combining the first principles calculations and analytical models, we demonstrate that the quantum anomalous Hall phase and chiral topological superconducting phase can be realized in this system. We find that to achieve time-reversal-breaking topological phases in anti-ferromagnetic materials, it is essential to break the combined symmetry of time reversal and inversion, which generally exists in anti-ferromagnetic structures. As a result, we can utilize an external electric gate voltage to induce the phase transition between topological phases and trivial phases, thus providing an electrically controllable topological platform for the future transport experiments.

MA 52.5 Thu 16:15 POT 251

Surface state-dominated photoconduction and THz-generation in topological Bi_2Te_2Se-nanowires — •Marinus Kundinger[1], Paul Seifert[1], Kristina Vaklinova[2], Klaus Kern[2,3], Marko Burghard[2], and Alexander Holleitner[1] — [1]Walter Schottky Institut and Physics-Department, Technical University of Munich, Am Coulombwall 4a, D-85748 Garching, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [3]Institut de Physique, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Topological insulators constitute a fascinating class of quantum materials with non-trivial, gapless states on the surface and trivial, insulating bulk states. In revealing the optoelectronic dynamics in the whole range from femto- to microseconds, we demonstrate that the long surface lifetime of Bi_2Te_2Se-nanowires allows to access the surface states by a pulsed photoconduction scheme and that there is a prevailing bolometric response of the surface states. The interplay of the surface state dynamics on the different timescales gives rise to a surprising physical property of Bi_2Te_2Se-nanowires: their pulsed photoconductance changes polarity as a function of laser power. Moreover, we show that single Bi_2Te_2Se-nanowires can be used as THz-generators for on-chip high-frequency circuits at room temperature. Our results open the avenue for single Bi_2Te_2Se-nanowires as active modules in optoelectronic high-frequency and THz-circuits.

We acknowledge financial support by the DFG priority program SPP 1666 'topological insulators'.

MA 52.6 Thu 16:30 POT 251

THz radiation induced helicity sensitive photocurrents in type-II GaSb/InAs quantum well structures — •Helene Plank[1], Johanna Pernul[1], Tanja Hummel[1], Georg Knebl[2], Pierre Pfeffer[2], Martin Kamp[2], Susanne Mueller[3], Thomas Tschirky[3], Sergey A. Tarasenko[4], Werner Wegscheider[3], Sven Höfling[2,5], and Sergey D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]Technische Physik University of Würzburg, Würzburg, Germany — [3]ETH Zurich, Solid State Physics Laboratory, Zurich, Switzerland — [4]Ioffe Institute, St.Petersburg, Russia — [5]University of St. Andrews, St. Andrews, United Kingdom

We report on the observation of terahertz radiation induced helicity sensitive photocurrents in GaSb/InAs quantum wells in the inverted regime. The photocurrent reverses its direction upon switching the circular polarization from left- to right-handed. The origin of the photocurrent depends on the experimental geometry and the Fermi energy position. For illuminating the sample centre, it stems from asymmetric scattering of free carriers excited by electric THz field [1]. At normal incidence or for Fermi energies in the gap it vanishes. The situation changes at the sample edges, where is it observed for both cases. We show that this edge current is caused by optical excitation of helical edge states in 2D topological insulators. The observed sign inversion upon changing the photon helicity is attributed to selection rules of optical transitions. We discuss the photocurrent behaviour and present microscopic models. [1] H. Plank *et al.*, Physica E **85**, 193 (2017).

MA 53: Focus Session: Topology meets Magnetism

Organized by Jürgen Henk, and Ingrid Mertig (Martin-Luther-Universität Halle)

The assembly of topology and electronic structure theory has brought condensed matter physics to a new summit. Recent highlights are the discoveries of topological insulators as well as Dirac and Weyl semimetals, bringing exotic surface states and transport phenomena into the focus of todays research. Could topology inspire the field of magnetism likewise? This question is answered by leading experts from both experimental and theoretical physics in this session. The subjects comprise Skyrmions as well as topological magnon insulators and semimetals, with foci on transport phenomena and the topological properties of magnons.

Time: Thursday 15:00–17:45 Location: HSZ 01

Invited Talk MA 53.1 Thu 15:00 HSZ 01

Topological phases for magnons and electrons in the skyrmion lattice — •Joaquín Fernandez-Rossier — QuantaLab, International Iberian Nanotechnology Laboratory (INL), Braga, Portugal

In this talk I will present two topological phases driven by a skyrmion lattice. First, I will discuss the electronic Quantum Anomalous Hall phase predicted to occur when graphene is placed on top of a triangular skyrmion lattice [1]. Second, I will show that the spin waves associated to a skyrmion lattice have a finite Berry curvature and a non-zero Chern number, forming thereby a phase topologically different from spin waves in conventional ground states [2]. The skyrmion lattice emerges spontaneously as a competition between ferromagnetic exchange, Dzyalonshinkii-Moriya interactions, Zeeman coupling and uniaxial anisotropy in a triangular lattice. I discuss the properties of the resulting topological spin-wave edge states, most notably their unidirectional propagation.

[1] Quantum Anomalous Hall effect in graphene coupled to skyrmions

J. L. Lado , J. Fernandez-Rossier Physical Review B 92, 115433 (2015)

[2] Topological spin waves in the atomic-scale magnetic skyrmion crystal

A. Roldan-Molina, A. S. Nunez, J. Fernandez-Rossier, New Journal of Physics 18, 045015 (2016)

Invited Talk MA 53.2 Thu 15:30 HSZ 01

Thermal Hall Effect of Spin Excitations in Quantum Magnets — •Max Hirschberger[1], Robin Chisnell[2], Jason W. Krizan[3], Young S. Lee[2], Robert J. Cava[3], and N. Phuan Ong[1] — [1]Department of Physics, Princeton University, USA — [2]Department of Physics, Massachusetts Institute of Technology, USA — [3]Department of Chemistry, Princeton University, USA

In magnetic materials without delocalized electrons, the thermal Hall effect κ_{xy} is a sensitive tool to explore the topological properties of low-energy magnetic (spin) excitations in a magnetic field. For magnetically ordered systems, κ_{xy} is a direct probe of the Berry curvature of the quasiparticle bands. We will illustrate this point using our experimental results for the 2D layered Kagome ferromagnet Cu(1,3bdc). Moreover, we will discuss our measurements of a large κ_{xy} on the frustrated pyrochlore quantum spin ice $Tb_2Ti_2O_7$, and its close relative $Yb_2Ti_2O_7$. Finally, we highlight the absence (to our resolution) of a thermal Hall signal in many other frustrated magnetic systems we have studied recently.

15 min. break

Invited Talk MA 53.3 Thu 16:15 HSZ 01

Magnon-mediated Dzyaloshinskii-Moriya torques, heat pumping, and spin Nernst effect — •Alexey Kovalev — University of Nebraska-Lincoln, USA

We predict that a temperature gradient can induce a magnon-mediated spin Hall response in a collinear antiferromagnet with Dzyaloshinskii-Moriya interactions [1]. To address this problem, we develop a linear response theory based on the Luttinger approach of the gravitational scalar potential which gives a general condition for a Hall current to be well defined, even when the thermal Hall response is forbidden by symmetry. We apply our theory to honeycomb lattice antiferromagnet and study a role of magnon edge states in a finite geometry. As examples, we consider single and bi-layer honeycomb antiferromagnets where the nearest neighbor exchange interactions and the second nearest neighbor DMI are present. From our analysis, we suggest looking for the magnon-mediated spin Nernst effect in insulating antiferromagnets that are invariant under (i) a global time reversal symmetry or under (ii) a combined operation of time reversal and inversion symmetries. In both cases, the thermal Hall effect is zero while the spin Nernst effect could be present. We also consider transport of magnons and its relation to non-equilibrium magnon-mediated spin torques [2]. We apply our theory to the magnon-mediated Nernst and torque responses in systems realizing Weyl magnons.

[1] Phys. Rev. Lett. 117, 217203 (2016)

[2] Phys. Rev. B 93, 161106 (2016)

Invited Talk MA 53.4 Thu 16:45 HSZ 01

Magnon companion pieces to electronic topological materials — •Alexander Mook[1], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Deutschland — [2]Martin-Luther-Universität Halle-Wittenberg, Halle, Deutschland

Topology has conquered the field of condensed matter physics with the discovery of the quantum Hall effect. Since then the zoo of topological materials is steadily increasing. In this talk, I demonstrate how to realize different topological phases with magnons: the magnon pendants to topological insulators as well as Weyl and nodal-line semimetals are presented.

Magnon bulk spectra are characterized by topological invariants, dictating special surface properties. For instance, the bulk bands of topological magnon insulators carry nonzero Chern numbers, causing topological magnon edge states that unidirectionally revolve the sample. Magnon Weyl semimetals possess zero-dimensional band degeneracies acting as source and sink of Berry curvature; at their surface they feature "magnon arcs" connecting the surface projections of Weyl points. Magnon nodal-line semimetals exhibit one-dimensional band degeneracies, i.e., closed loops in reciprocal space. Surface projections of these nodal lines host "drumhead" surface states whose details depend strongly on the surface termination.

I discuss possible material candidates and experiments for the identification of these novel states of matter.

Invited Talk MA 53.5 Thu 17:15 HSZ 01

Nonreciprocal propagation of elementary excitations in noncentrosymmetric magnets — •Yoshinori Onose — University of Tokyo, Tokyo, Japan

Simultaneous breaking of spatial inversion and time-reversal symmetries completely lifts the degeneracy between +k and -k states of elementary excitations in solids. In this case, the decay rate and phase velocity depends on the sign of k, and, hence, the propagation of the elementary excitation becomes nonreciprocal. The photonic nonreciprocity, which is denoted as magnetochiral or optical magentoelectric effect, has been investigated extensively in the last two decades. Here, we experimentally study the nonreciprocal propagation of magnons and acoustic waves as well as microwaves in noncentrosymmetric magnets.

MA 54: Spin Hall Effects and Skyrmions II

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

MA 54.1 Thu 15:00 HSZ 04

Dzyaloshinkii-Moriya Iinteraction and Hall Effects in Disordered Bulk Chiral Magnets From First Principle Calculations — •Jacob Gayles[1], Frank Freimuth[2], Charles Spencer[3], Rembert Duine[4], Chris Marrows[3], Yuriy Mokrousov[2], Stefan Blügel[2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Institute for Theoretical Physics, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands — [4]School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, United Kingdom

We demonstrate that the electron dynamics in the skyrmion phase of Fe-rich MnFeGe and FeCoGe alloys is governed by Berry phase physics. We observe that the magnitude of the Dzyaloshinskii-Moriya interaction, directly related to the mixed space-momentum Berry phases, changes sign and magnitude with concentration x in direct correlation with the data of Shibata et al., Nature Nanotech. 8, 723 (2013). The computed anomalous and topological Hall effects in FeGe are also in good agreement with available experiments. We further develop a simple tight-binding model able to explain these findings. We show that the adiabatic Berry phase picture is violated in the Mn-rich limit of the alloys. Lastly, we make connections between experiment and computation in disordered regime.

MA 54.2 Thu 15:15 HSZ 04

Skyrmions and magnetic singularities in confined geometries — •Gideon P. Müller, Nikolai S. Kiselev, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Interest in chiral magnetic skyrmions is rising because they are suggested as new information carriers in spintronic devices, such as the skyrmion racetrack. This necessitates a deep understanding of the mechanism of skyrmion nucleation and anihilation in these systems. We apply the recently proposed geodesic nudged elastic band method to explore different skyrmion nucleation/annihilation mechanisms in the systems by analysing corresponding minimum energy paths (MEPs) and energy barriers. We compare such MEPs for skyrmion nucleation with different geometries, in particular thin films, nanostripes and nanowires. For the case of nanowires in a certain range of material parameters we found stable particle-like objects composed of coupled magnetic singularities known as Bloch points. The discovery of this effect can have potential application in spintronics.

MA 54.3 Thu 15:30 HSZ 04

Edge instabilities and skyrmion creation in magnetic layers — •Jan Müller[1], Achim Rosch[1], and Markus Garst[2] — [1]Institut für Theoretische Physik, Universität zu Köln, D-50937 Köln, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany

We study both analytically and numerically the edge of two-dimensional ferromagnets with Dzyaloshinskii-Moriya (DM) interactions, considering both chiral magnets and magnets with interface-induced DM interactions. We show that in the field-polarized (FP) ferromagnetic phase magnon states exist which are bound to the edge, and we calculate their spectra within a continuum field theory. Upon lowering an external magnetic field, these bound magnons condense at a finite momentum and the edge becomes locally unstable. Micromagnetic simulations demonstrate that this edge instability triggers the creation of a helical phase which penetrates the FP state within the bulk. A subsequent increase of the magnetic field allows to create skyrmions close to the edge in a controlled manner.

MA 54.4 Thu 15:45 HSZ 04

Skyrmion-Antiskyrmion pair creation by in-plane currents — •Martin Stier[1], Wolfgang Häusler[2], Thore Posske[1], Gregor Gurski[1], and Michael Thorwart[1] — [1]Universität Hamburg, Germany — [2]Universität Augsburg, Germany

Magnetic Skyrmions are considered to be topologically protected particles. Due to this stability, their small size and the possibility to move them by low electric currents they are proper candidates for spintronic devices. However, without violating this topological protection, it is should be possible to create Skyrmion-Antiskyrmion pairs as long as the total Skyrmion number does not change. In fact, we derive a Skyrmion equation of motion and show that electric currents can create such Skyrmion-Antiskyrmion pairs. By this equation of motion we are able to give general prerequisites for this pair creation process. We confirm these results by numerical simulations. On a lattice, where topological protection gets imperfect, the Antiskyrmions in these pairs can be destroyed and only the Skyrmions remain. This eventually changes the total Skyrmion number and yields new ways of creating and controlling Skyrmions.

MA 54.5 Thu 16:00 HSZ 04

Skyrmion Hall Effect Revealed by Direct Time-Resolved X-Ray Microscopy — •Kai Litzius[1,2,3], Ivan Lemesh[4], Benjamin Krüger[1], Pedram Bassirian[1], Lucas Caretta[4], Kornel Richter[1], Felix Büttner[4], Koji Sato[5], Oleg A. Tretiakov[5,6], Johannes Förster[3], Robert M. Reeve[1], Markus Weigand[3], Iuliia Bykova[3], Hermann Stoll[3], Gisela Schütz[3], Geoffrey S. D. Beach[4], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [4]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — [5]Tohoku University, Sendai 980-8577, Japan — [6]School of Natural Sciences, Far Eastern Federal University, Vladivostok

Magnetic skyrmions are topologically stabilized nanoscale spin structures that show promise for future spintronic devices if they can be moved reliably. Employing scanning transmission x-ray microscopy, we demonstrate reproducible skyrmion trajectories at room temperature in ultrathin multilayer films driven by spin orbit torques [1]. We identify a sizeable skyrmion Hall effect that depends on the velocity, which is not captured using the previously used rigid skyrmion model. We explain our observation based on eigenmode excitations that deform the skyrmion during motion [1].

[1] K. Litzius et al., Nature Physics (in press 2016), arxiv:1608.07216.

15 min. break.

MA 54.6 Thu 16:30 HSZ 04

Impact of the chemical nature of defects on the pinning of magnetic skyrmions. — •Imara L. Fernandes, Juba Bouaziz, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Owing to their topology, magnetic skyrmions are considered as potential particles for future information technology. The low current densities estimated to move them in a racetrack memory promises devices of low energy consumption. One issue that is currently discussed is the speed of skyrmions. Experiments indicate that skyrmions are more than one order of magnitude slower than domain walls. In a device, skyrmions interact with defects, affecting their creation, stability and motion. Following our previous study [1], we investigate purely from a full *ab initio* description based on density functional theory (DFT) the impact of 3d and 4d impurities on the energetics, electronic and magnetic properties of realistic nano-skyrmions created in Pd/Fe/Ir(111) substrate. With a careful analysis of the hybridization of the electronic states, we identify the important mechanisms behind the expulsion or pinning of single magnetic skyrmions as function of the chemical nature of the impurities that translate on a bigger picture to an energy landscape with attractive and repulsive potentials determining the skyrmion motion.

[1] D.M. Crum *et al.*, Nat. Comms. **6**, 8541 (2015).

Funding provided by the ERC-consolidator grant Dynasore and CNPq (Brazil).

MA 54.7 Thu 16:45 HSZ 04

Hydrogen-Induced Skyrmions in Ultrathin Iron Films — •Pin-Jui Hsu, Lorenz Schimdt, Aurore Finco, Niklas Romming, Andre' Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Germany

Chiral magnetic states, such as chiral domain walls, spin spirals, and magnetic skyrmions, have recently been observed in magnetic films on heavy metal substrates due to a sizable interfacial Dzyaloshinskii-Moriya (DM) interaction and a lack of spatial inversion symmetry at surfaces and interfaces. In the present work, we report on the emergence of individual magnetic skyrmions by dosing atomic hydrogen onto Fe double-layers (Fe-DL) grown on Ir(111). A spin spiral ground state was recently found for clean pseudomorphic Fe-DL with a rather short period of about 1.3 nm, which remains stable up to 9 T out-of-plane field without transition to a skyrmionic state [1]. After introducing atomic hydrogen, the pseudomorphic strained Fe-DL exhibits a p(2x2)-structure and a spin spiral ground state in zero field with an increased periodicity of up to 4.0 nm. Upon application of an external out-of-plane magnetic field, isolated magnetic skyrmions appear on the hydrogenated Fe-DL as directly observed by in-situ SP-STM measurements. Hydrogenation of magnetic thin films therefore appears as an interesting alternative for tuning the properties of chiral non-collinear spin textures, besides magnetic multilayer technologies.[1] P.-J. Hsu, A. Finco, L. Schmidt, A. Kubetzka, K. v. Bergmann, R. Wiesendanger, Phys. Rev. Lett. 116, 017201 (2016)

MA 54.8 Thu 17:00 HSZ 04

Theory of inelastic electron scattering by spin waves in noncollinear magnets — •Flaviano José Dos Santos, Manuel Dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52428 Jülich, Germany

Electron Energy Loss Spectroscopy is an invaluable tool for probing the spin wave excitations of thin ferromagnetic films [1]. However, to our knowledge no EELS experiment has been attempted for antiferromagnetic or non-collinear magnetic systems. With the aim to characterize the spin wave excitations in novel magnetic phases of matter, we developed and implemented a quantum mechanical description of inelastic electron scattering for arbitrary magnetic structures, using information from first principles calculations. We discuss the role of the spin polarization of the incoming and outgoing electrons, and the contribution from the four possible scattering channels to the inelastic cross-section. We illustrate the formalism for three model systems: a ferromagnet with Dzyaloshinksii-Moriya interaction, its spin spiral counterpart, and a skyrmionic lattice. For the latter we also make use of first-principles calculations for the experimentally well-characterized Pd/Fe/Ir(111) bilayer [2,3].

This work is supported by the HGF-YIG Programme VH-NG-717 (Funsilab) and by the Brazilian funding agency CAPES.

References: [1] Ibach, H., Surf. Sci. 630, 301-310 (2014) [2] Romming, N., et al. Phys. Rev. Lett. 114, 177203 (2015) [3] Crum, D., et al. Nat. Commun. 6, 8541 (2015)

MA 54.9 Thu 17:15 HSZ 04

Spin Pumping And Inverse Spin-Hall Effect In PEDOT:PSS — •Mohammad Qaid[1], Tim Richter[1], Alexander Müller[1], Christoph Hauser[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich Damerow Straße 4, 06120 Halle

Recently the inverse spin-Hall effect in conducting polymers was measured [1,2]. Here we present a study of spin pumping and ISHE in hybrid structures composed of thin film yttrium-iron garnet (YIG) and PEDOT:PSS and Pt contacts. Our experiments indicate an ISHE indeed exists but is much smaller than previously published. Control experiments show that spin pumping through the PEDOT:PSS can be highly efficient and massive artifacts can occur due to ISHE in the electrical contacts. Large magnon propagation lengths in the YIG can induce spin pumping far away from the excitation source and underneath the contacts. Only for dedicated geometries it is possible to prevent these artifacts and to quantify the ISHE in the conducting polymer. We will discuss the ISHE and also strategies to avoid a number of highly relevant artefacts which have exactly the same signature as the ISHE.

References
1.K. Ando, et al., Nat. Mater. 12, 622 (2013)
2.D. Sun, et al., Nat. Mater.15, 863 (2016)

MA 54.10 Thu 17:30 HSZ 04

Magnetic and chiral properties of epitaxial Pt/Co_n/Ir(111) films investigated by SP-STM — •Marco Perini, André Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

Magnetic skyrmions are promising candidates for future spintronics technology. They have been recently observed at room temperature with different techniques in cobalt-based multilayered thin films [1,2]. The cobalt layer is placed between two heavy metals to provide a strong interfacial Dzyaloshinskii-Moriya interaction (iDMI). However, the details of the spin structure in these films remain elusive due to the limited spatial resolution of the applied techniques.

In this work we performed low-temperature spin-polarized scanning tunneling microscopy (SP-STM) on epitaxially grown Co/Ir(111) and Pt/Co/Ir(111) ultrathin films. We observe large-scale magnetic domains, on the order of hundreds of nanometers, separated by sharp domain walls, only a few nanometers wide. We show that these walls possess a unique rotational sense, a sign of a strong DMI at the Co/Ir interface, which produces Néel-type domain walls. In addition, measuring the domain wall width as a function of Co and Pt thickness provides information on the magnetic parameters of these systems, such as A, K and D.

[1] Moreau-Luchaire et al., Nat. Nano. 11, 444-448 (2016), [2] Boulle et al., Nat. Nano. 11, 449-454 (2016)

MA 54.11 Thu 17:45 HSZ 04

Magnetic skyrmions in Pt/Co/Ir at zero field — •Jochen Wagner[1], Robert Frömter[1], Kai Bagschik[1], André Philippi-Kobs[2], Rustam Rysov[2], Leonard Müller[2], Gerhard Grübel[2], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Uni Hamburg, Germany — [2]DESY, Hamburg, Germany

X-ray holographic microscopy (XHM) has become a competitive technique to investigate magnetic domain patterns with sub-20-nm spatial resolution exploiting the x-ray magnetic circular dichroism [1].

We employed XHM to study a wedge-grown $(Pt_{1nm}/Co_{0-2nm}/Ir_{1nm})_6$ multilayer. The absence of inversion symmetry yields a strong interfacial Dzyaloshinskii-Moriya interaction (DMI), which causes domain walls to be Néel like – in contrast to Pt/Co/Pt, where Bloch walls are expected. As a further, the consequence stabilization of skyrmionic bubbles and even skyrmion lattices through magnetic fields has been reported recently [2].

In the demagnetized state, we find the maze domain pattern with cobalt-thickness dependent domain sizes ranging from 100 nm to a few microns. In addition, circular domains of about 30 nm diameter are observed, unlike in symmetrical systems like Pt/Co/Pt. With the strong DMI present, these bubble domains can be considered as skyrmions. The skyrmions can be deleted by fully saturating the sample, and reappear after another demagnetization cycle. We assume therefore local defects to be responsible for their creation and zero-field stability.

[1] D. Stickler, et al., Appl. Phys. Lett. 96, 042501 (2010).
[2] C. Moreau-Luchaire et al., Nature Nanotech 11, 444-448 (2016).

MA 55: Thin Films: Magnetic Anisotropy

Time: Thursday 15:00–18:00 Location: HSZ 101

MA 55.1 Thu 15:00 HSZ 101

New magnetic anisotropy control in thin film multilayers for sensing applications — •Svenja Willing[1], Kai Schlage[1], Lars Bocklage[1,2], Guido Meier[2,3], and Ralf Röhlsberger[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Max-Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

Magnetic field sensors are frequently used in today's automotive control, industrial process management, and information technology. Sensors based on the giant magnetoresistance are small, low-cost, and easy to produce. They can be as simple as a sandwich of two magnetic layers separated by a non-magnetic spacer layer. Exposing such a trilayer to a magnetic field influences the relative orientation of magnetization in the layers which can be detected as a change in electrical resistance. Recently, the magnetic and magneto-resistive properties of such multilayers stacks were tuned by deposition at oblique incidence angles [1]. The induced shape anisotropy enables full control over each individual layer's coercivity and preferred magnetic orientation without the limitations of interlayer exchange or exchange-biased pinning. This allows for a versatile, individual tailoring of multilayer functionalities to adapt the sensor to the needs of an application. We show how microstructuring influences the magnetic and magneto-resistive properties of the multilayer devices.

[1] K. Schlage, L. Bocklage, D. Erb, J. Comfort, H.-C. Wille, R. Röhlsberger, Adv. Funct. Mater. 2016, 26, 7423-7430.

MA 55.2 Thu 15:15 HSZ 101

A new interstitial compound: Fe-B — •Dominik Gölden, Erwin Hildebrandt, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

One of the most promising potential permanent magnet candidates of the last decades, α''-$Fe_{16}N_2$, has a low decomposition temperature of about 180 °C, making it unsuitable for many applications. One alternative is replacing the nitrogen interstitials with boron. This system is predicted to yield similar or even higher saturation magnetization and anisotropy while having a higher decomposition temperature. Previous studies suggest that boron prefers to occupy substitutional positions over interstitial positions. We explored the Fe-B system with boron content below 15% by molecular beam epitaxy (MBE). An increasing tetragonalization was observed, pointing at an interstitial occupation of boron. The measured c/a ratio increased with decreasing growth temperature and scaled linearly with the boron content up to a maximum of 1.07 with a magnetization of about 1580 emu/cm^3. However, in contrast to nitrogen interstitials, the interstitial Fe-B system could be grown at up to 300 °C, making it potentially a much more interesting candidate for permanent magnets.

MA 55.3 Thu 15:30 HSZ 101

Impact of Au interlayer on magnetoelasticity of Fe/Au/Fe sandwich — •Kenia Novakoski Fischer and Dirk Sander — Max Plack Institute of Microstructure Physics - Halle

Magnetic metallic structures separated by a nonmagnetic spacer are used in magnetic recording media and related devices. The interlayer exchange coupling between ferromagnetic (FM) layers shows an oscillatory response as a function of the spacer thickness. This effect is attributed to the influence of the quantum-well states in the nonmagnetic layer [1]. In this work, we shed light on the understanding of the impact of this nonmagnetic spacer layer on the magnetoelastic coupling of ferromagnetic films. The magnetoelastic coupling coefficients are obtained from measurements of the stress change of FM layers upon a magnetization reorientation [2]. We acquire the values of the magnetoelastic coupling coefficient B1 for Fe (15 ML)/Au (X ML)/Fe (10 ML) layers on Au (001), where X varies from 0 to 12 ML. Up to 2 ML Au, B1 remains constant at -1.3 MJ/m3. With increasing Au thickness B1 exhibits a non-monotonic behavior. We observe a non-monotonic variation of magnitude 3 MJ/m3 in an increment of Au thickness of 1 ML at a spacer thickness near 9 ML. The results of the magnetoelastic coupling in the Fe films sandwiched by Au are discussed in view of the interlayer exchange coupling of the ferromagnetic layers.

[1] J.E. Ortega et al., Phys. Rev. B 47, 1540, (1993); J. Unguris et al., Phys. Rev. B 75, 6437, (1994); W. Geerts et al., Phys. Rev. B 17, 12581, (1994).

[2] D. Sander, Rep. Prog. Phys. 62, 809 (1999).

MA 55.4 Thu 15:45 HSZ 101

Epitaxial YCo_5 thin films with perpendicular anisotropy — •Shalini Sharma, Erwin Hildebrandt, Iliya Radulov, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

Thin films with perpendicular magnetic anisotropy are particularly important for high-density perpendicular magnetic recording media, magneto-optical recording media, and recently emerging nano-scale spintronic devices. One approach to achieve this is the c-axis (easy axis) textured growth of materials which possess strong intrinsic magnetocrystalline anisotropy that is large enough to overcome the shape anisotropy of thin films. This work is focused on growing thin films of YCo_5 which possesses a very strong uniaxial magnetocrystalline anisotropy (K_1 of 5.78 MJ/m^3) as bulk phase. We have explored the growth window of (00l) oriented YCo_5 thin films grown onto (0006) Al_2O_3 substrates by molecular beam epitaxy (MBE). The hexagonal YCo_5 phase grows with the c-axis perpendicular to the film plane without the use of any additional buffer layer. The highest coercivity was measured to be 4 kOe with a saturation magnetization of 517 emu/cc at 300 K. This is the highest value of magnetization ever reported for YCo_5 thin films. Magnetic torque measurements were used to calculate the value of anisotropy constant, K_1.

MA 55.5 Thu 16:00 HSZ 101

Mn-Fe-Ga Films with Perpendicular Magnetic Anisotropy — •Anastasios Markou[1], Adel Kalache[1], Susanne Selle[2], Gerhard H. Fecher[1], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Fraunhofer Institute for Microstructure of Materials and Systems IMWS, 06120 Halle, Germany

Heusler compounds are a remarkable class of materials with a huge potential for different applications [1]. Tetragonally distorted Mn-based Heusler compounds (Mn_3Ga and Mn_3Ge) are promising class of materials, showing high magnetocrystalline anisotropy, large coercivity and high Curie temperature, but suffer from low magnetization [2]. The substitution of Mn with Fe in D022-Mn3Ga can lead to magnetization increment and making Mn-Fe-Ga compound a candidate material for rare-earth-free permanent magnets. Here, we present a systematic X-ray diffraction (XRD), transmission electron microscopy (TEM) and magnetic characterization of Mn-Fe-Ga films with different compositions and perpendicular anisotropy.

[1] C. Felser, L. Wollmann, S. Chadov, Gerhard H. Fecher and S.S.P Parkin, APL Mater. 3, 041518 (2015).

[2] A. Kalache, G. Kreiner, S. Quardi, S. Selle, C. Patzig, T. Hoche and C. Felser, APL Mater. 4, 086113 (2016)

15 min. break.

MA 55.6 Thu 16:30 HSZ 101

Magnetic characterization of the nanolaminated Mn2GaC MAX phase — •Iuliia Novoselova[1], Ruslan Salikhov[1], Arni S. Ingason[2], Johanna Rosen[2], Ulf Wiedwald[1], and Michael Farle[1,3] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Duisburg, Germany — [2]Department of Physics, Linköping University, Linköping, Sweden — [3]Center for Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, Kaliningrad, Russia

We report on the magnetic properties of the new magnetic material Mn_2GaC MAX phase [1]. MAX phases are atomically laminated compounds composed of early transition metals M, A - group elements and X is C or N. The crystal structure of MAX phases is hexagonal with M-X-M atomic layers stacking in the c-direction with the A-element as a spacer [2]. Mn_2GaC has been synthesized as a epitaxial film containing Mn as an exclusive M element. First principles calculations suggest that the spins in a Mn-C-Mn trilayer are ferromagnetically ordered, however, the antiferromagnetic (AFM) and ferromagnetic (FM) spin alignments in Mn-Ga-Mn chains are competitive [2]. This competition leads to a rich magnetic phase diagram and structural changes linking to temperature-dependent magnetic order and anisotropy [2].

In-plane alignment of magnetic moments caused by the film shape anisotropy below 240 K has been confirmed using ferromagnetic resonance (FMR). Magnetometry measurements reveal hysteretic behavior with the magnetic moment of 1.7 μB per Mn atom at saturation. Work supported by DFG, SA 3095/2-1. [1] A. S. Ingason et al., MRL, 2, 89 (2014). [2] A. S. Ingason et al., J. Phys.: Cond. Mat., 28, 433003 (2016).

MA 55.7 Thu 16:45 HSZ 101

MAX phase magnetic quaternary compounds — •Ruslan Salikhov[1], Quanzheng Tao[2], Iuliia Novoselova[1], Johanna Rosen[2], Ulf Wiedwald[1], and Michael Farle[1,3] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Department of Physics, Linköping University, Sweden — [3]Center for Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, Kaliningrad, Russia

Mn+1AXn (n = 1-3) phases, for which M is an early transition metal, A is an A-group element, and X is C (or N), are a family of inherently nanolaminated hexagonal compounds. Due to their unique structure these materials share properties usually associated with ceramics and metals [1]. The ability to stabilize quaternary compounds with isostructural solutions on M and A sites and with different stoichiometry yields a class of new magnetic MAX phase materials. We report on the magnetic properties of the recently discovered compounds: (Cr0.5Mn0.5)2GaC [2], (Mo0.5Mn0.5)2GaC [3], (Cr0.5Mn0.5)2AuC and (V,Mn)3GaC2 [4]. The (Cr0.5Mn0.5)2AuC system shows the smallest magnetic ordering temperature of TC = 120 K, high coercive field of HC = 100 mT and magnetocrystalline anisotropy energy (MAE) at T = 10 K. The MAE of (Cr0.5Mn0.5)2GaC and (Mo0.5Mn0.5)2GaC do not exceed 4 kJ/m3, both systems have similar TC = 210 K and HC = 30 mT at T = 5 K. This work is supported by DFG SA 3095/2-1. [1] M. W. Barsoum, PSSC, 28, 201 (2000). [2] R. Salikhov et al., MRL, 3, 156 (2015). [3] R. Meshkian, et al., APL Mater. 3, 076102 (2015). [4] Q. Tao, et al., APL Mater. 4, 086109 (2016).

MA 55.8 Thu 17:00 HSZ 101

Compensated magnetic state in tetragonal thin films for antiferromagnetic spintronics — •Roshnee Sahoo[1], Ajaya K. Nayak[2], Lukas Wollmann[1], Stuart Parkin[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

Heusler compounds are well known for their potential applications in spintronics [1]. In recent years, antiferromagnetic spintronics has received much attention since ideal antiferromagnets do not produce stray fields and are much more stable to external magnetic fields compared to materials with net magnetization. Similar to antiferromagnets, compensated ferrimagnets have zero net magnetization but have the potential for large spin-polarization and strong out of plane magnetic anisotropy. In the present work, we report a completely compensated magnetic state and tunable magnetic anisotropy in Mn-Pt-Ga based tetragonal thin films [2]. It is also demonstrate that bilayers formed from compensated and uncompensated Mn-Pt-Ga layers, exhibit a large interfacial exchange bias field up to room temperature.The present system establishes a distinct approach of designing spintronic devices that are formed from materials with similar elemental compositions and nearly identical crystal and electronic structures, and, hence, are of significant practical value due to their high thermal stabilities.
[1]C. Felser et al, Appl. Phys. Lett. Mater.**3**, 041518 (2015).
[2]R. Sahoo et al, Adv. Mater.**28**, 8499-8504 (2016).

MA 55.9 Thu 17:15 HSZ 101

Probing the strain induced magnetic anisotropy in $CoCr_2O_4$ with x-ray magnetic circular dichroism (XMCD) — •Cinthia Piamonteze[1], Yoav William Windsor[1], Sridhar Reddy Avula Venkata[1], Andrea Scaramucci[2,3], Jeroen A. Heuver[4], Beatriz Noheda[4], and Urs Staub[1] — [1]PSI, SLS, Villigen, Switzerland — [2]Mater. Theory, ETHZ, Zürich, Switzerland — [3]Lab. Scient. Devel. and Novel Mater., PSI, Villigen, Switzerland — [4]Zernike Inst. Adv. Mater., Univ. Groningen, Groningen, The Netherlands

$CoCr_2O_4$ (CCO) is a spinel where Co^{2+} and Cr^{3+} occupy tetrahedral and octahedral sites, respectively. CCO is one of the few single-phase multiferroic systems exhibiting a net magnetic moment [1]. It exhibits a collinear ferrimagnetic order below 95K. Below 27K a spiral spin component appears in concomitance with a ferroelectric polarization [2]. Recently it has been shown that strain engineering can successfully control the magnetic easy axis of CCO thin films between in-plane and out-of-plane [3]. In this work we present XMCD and element specific hysteresis curves at the Co and the Cr $L_{3,2}$ edges for both compressive and tensile strained 40-nm-thick films. We explain the behavior of the magnetocrystalline anisotropy using quantitative values of the orbital and spin moments of Co, obtained through sum rule analysis. We specifically show that the ratio of m_L/m_S along the easy axis direction is 0.24 and 0.3 for tensile and compressive strain, respectively, pointing to a large Co orbital contribution. [1] Yamasaki *et al.* PRL **96**, 207204 (2006). [2] Y. Choi *et al.*, PRL **102**, 067601 (2009). [3] J. A. Heuver *et al.*, PRB **92**, 214429 (2015).

MA 55.10 Thu 17:30 HSZ 101

Metadynamic study on magnetic anisotropy of thin films — •Balazs Nagyfalusi[1], Laszlo Udvardi[2,3], and Laszlo Szunyogh[2,3] — [1]Wigner Research Center for Physics, Budapest, Hungary — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary — [3]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budapest, Hungary

Magnetic anisotropy plays key role in several phenomena having importance in technological applications. In the present contribution the temperature dependence of the magnetic anisotropy energy (MAE) is investigated by means of metadynamic Monte Carlo simulations. Metadynamics[1] is an adaptive biasing potential methods where the free energy of the system is explored along a collective variable (CV).

We studied a model of a ferromagnetic thin film with uniaxial on-site and two-site anisotropy. The CV has been chosen to be the normalized component of the magnetization perpendicular to the substrate. The temperature dependence of MAE provided by the simulations is in good agreement with the Callen-Callen[2] theory in the case of on-site only anisotropy and an exponent close to 2 has been found at higher temperatures for the model containing two-site anisotropy. The competition of the on-site and two-site anisotropy may result in a reorientation of the magnetization which has been also confirmed by our simulations for mono and bi-layers.
[1] A. Laio, M. Parrinello, PNAS **99**, 12562 (2002)
[2] H.B. Callen and E. Callen, J. Phys. Chem. Solids, **27**, 1271 (1966)

MA 55.11 Thu 17:45 HSZ 101

Domain wall profiles in $Co/Ir_n/Pt(111)$ ultrathin films — György J. Vida[1], Eszter Simon[1], Levente Rózsa[2], Krisztián Palotás[3], and •László Szunyogh[1] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia

Motivated by recent experiments [1,2] we present a study of domain walls in $Co/Ir_n/Pt(111)$ ($n = 0, \ldots, 6$) films by a combined approach of first-principles calculations and spin dynamics simulations. We calculate the tensorial exchange interactions and the magnetic anisotropies for the Co overlayer and find strong out-of-plane magnetic anisotropy for the films with FCC geometry. We demonstrate that the rotational sense (chirality) of domain walls is changed upon the insertion of an Ir buffer layer as compared to the pristine Co/Pt(111) system, unambigously associated with the orientation of the in-plane components of the Dzyaloshinskii-Moriya (DM) vectors. Our simulations also indicate a twisting of the spins with respect to the planar domain wall profile on the triangular lattice. We discuss this domain wall twisting using symmetry arguments and by using an appropriate micromagnetic continuum model considering energy terms related to the out-of-plane component of the DM interaction as well as to specific symmetric off-diagonal elements of the exchange tensor. [3]

[1] G. Chen *et al.*, Nat. Comm. 4, 2671 (2013)
[2] A. Hrabec *et al.*, Phys. Rev. B 90, 020402 (2014)
[3] Gy. J. Vida *et al.*, arXiv:1611.09518 (2016)

MA 56: Bulk Materials: Soft and hard permanent magnets

Time: Thursday 15:00–18:00 Location: HSZ 403

MA 56.1 Thu 15:00 HSZ 403

Ab initio theory of Fe-based permanent magnets — •Olga Vekilova, Olle Eriksson, and Heike Herper — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

Strong permanent magnets are of great importance for many technological applications, from magnetic resonance imaging to green sources of energy. The modern society is currently interested in the design of magnetic materials that are cheaper and contain smaller amounts of rare earth elements compared with the existing ones. Theoretical modelling is a promising tool to discover new advanced rare earth-free permanent magnets. Good permanent magnet is a ferromagnetic compound with high Curie temperature, high saturation magnetization and high anisotropy energy. The latter is the key factor for the required large coercivity and in addition it should be uniaxial. The listed conditions are satisfied in Fe-rich materials, in particular in hexagonal Fe_3Sn. However, as it is known from both the experiment and the theory, the easy magnetization axis lies in the hexagonal plane. One of the possibilities for changing the easy axis direction is through alloying. We have studied the magnetic properties of Fe-based alloys with phase stabilizers, such as Sn, Sb, Ga, Ge and Si to find new ferromagnetic phases with uniaxial anisotropy suitable for the development of advanced permanent magnets. The calculated magnetocrystalline anisotropies and Curie temperatures of these compounds are analyzed and suggestions for the better permanent magnets are formulated. The work is supported by NOVAMAG (EU686056)

MA 56.2 Thu 15:15 HSZ 403

The influence of the Madelung potential on magnetic properties of disordered FePt — •Saleem Ayaz Khan[1], Peter Blaha[2], Hubert Ebert[3], Jan Minár[1,3], and Ondřej Šipr[1,4] — [1]New Technologies Research Centre University of West Bohemia, Pilsen, Czech Republic — [2]Institute of Materials Chemistry, TU Vienna, Austria — [3]Universität München, Department Chemie, Germany — [4]Institute of Physics ASCR v. v. i., Prague, Czech Republic

When dealing with substitutional alloys, the random occupation of sites has to be approximated. One can use supercells to include many different local configurations. Or one can rely on a mean field method such as the coherent potential approximation (CPA) to model the situation by an auxiliary effective medium. Computationally efficient single site CPA treats the disorder itself very efficiently. However, being a single-site method, it neglects the effect of fluctuations of the local environment. In particular, the Madelung contribution to the alloy potential cannot be included within the standard CPA.

To learn more about the local aspects of magnetism of disordered FePt, we performed a set of ab-initio relativistic full-potential calculations employing both the supercell approach and the CPA. The focus is on the trends of local magnetic moments with the chemical composition of the nearest neighbourhood of individual Fe and Pt atoms. A small but distinct difference between average magnetic moments obtained when using the supercells and when relying on the CPA is identified and linked to the neglect of the Madelung potential in the CPA.

MA 56.3 Thu 15:30 HSZ 403

Grain boundary diffusion of different rare earth elements in Nd-Fe-B sintered magnets by experiment and FEM simulation — •Konrad Loewe[1], Dimitri Benke[1], Christian Kübel[2], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]TU Darmstadt, FB Materials Science, 64287 Darmstadt — [2]KIT, Institute of Nanotechnology & Karlsruhe Nano Micro Facility, Hermann-von-Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

In the present work, we explore the influence of a surface-bulk coercivity gradient in Nd-Fe-B magnets produced by the Grain Boundary Diffusion Process (GBDP) on the overall coercivity. In our systematic and comprehensive study we diffused four different rare earth elements (Dy, Tb, Ce and Gd) in two different kinds of commercial Nd-Fe-B magnets, one very Dy-lean and one Dy-rich. By means of cutting the magnets into thin slices we obtain lateral coercivity profiles, from which diffusion constants are extracted. We find that in both magnets Tb diffuses significantly faster than Dy. Ce diffuses slightly slower than Dy and the overall coercivity decrease is similar for Ce and Gd. High-resolution scanning transmission electron microscopy shows the nano-scale distribution of Tb around the grain boundaries located in the bulk of the magnet. Finally, a simple model for the magnetization reversal in grain boundary diffusion processed gradient Nd-Fe-B magnets was developed and implemented into a FEM software. Our calculated demagnetization curves correspond very well for the Dy and Tb samples, but deviate significantly for Ce and Gd.

MA 56.4 Thu 15:45 HSZ 403

Reliability of bulk combinatorial reactive crucible melting approach to search for new permanent magnets: a Fe-Sn case study — •Bahar Fayyazi, Konstantin Skokov, Dmitriy Karpenkov, and Oliver Gutfleisch — Technical University of Darmstadt

The search for new magnetic materials using conventional equilibrated alloy methods is an expensive and time-consuming task. Therefore, high-throughput methods where multiple alloy compositions (material libraries) can be synthesized and characterized together would be a powerful tool. Reactive crucible melting (RCM) as well as diffusion couple/multiple approach are potential bulk high-throughput methods in order to speed up the discovery and examination of new materials. However, in previous investigations [1] by diffusion multiple approach, it has been found that under specific conditions there may exist some phases which are not forming by interdiffusion reactions. This assessment motivated us to evaluate whether a similar situation may occur in RCM method. Therefore, a detailed study has been conducted on the simple and well-studied Fe-Sn binary system by correlating the forming phases in reactive crucible samples to the known phase diagram. Simultaneously, under the same conditions as for the crucibles, 10 individual homogeneous samples were prepared by conventional metallurgy and the results were compared to RCM samples. Discrepancies which have been observed will be discussed in this work.

[1] J.C. Zhao, Reliability of the diffusion-multiple approach for phase diagram mapping, J. Mater. Sci., 39 (2004) 3913-3925.

MA 56.5 Thu 16:00 HSZ 403

Ferromagnetism vs. slow relaxation in Fe-doped Li_3N — •Manuel Fix[1], Rudra S. Manna[1], Stephan G. Jantz[2], and Anton Jesche[1] — [1]EP 6, Electronic Correlations and Magnetism, University of Augsburg, Germany — [2]Solid State Chemistry, Insitute of Physics, University of Augsburg, Germany

The compounds $Li_2(Li_{1-x}T_x)N$ where $T = \{$Mn, Fe, Co and Ni$\}$ show a highly anisotropic behaviour of their magnetic properties resulting from large orbital contributions to the magnetic moment of the transition metals [1,2]. In the case of Fe-doping, this results in a huge magnetic hysteresis with coercive fields of more than 11 T, tempting one to claim a ferromagnetic behaviour in the compound. On the other hand, $Li_2(Li_{1-x}Fe_x)N$ shows a pronounced time dependence of the magnetization, reminiscent of spin glasses or molecular magnets.

We will discuss the intriguing magnetic properties of $Li_2(Li_{1-x}Fe_x)N$. Isothermal magnetisation curves will be compared to direct measurements of the magnetic relaxation, as well as the frequency dependence of the ac-susceptibility. Furthermore, similarities between the hysteresis in magnetization and magnetostriction are going to be discussed.

[1] A. Jesche *et al.*, Phys. Rev. B **91**, 180403(R) (2015)
[2] A. Jesche *et al.*, Nature Comm. **5**:3333 (2014)

MA 56.6 Thu 16:15 HSZ 403

Producing two different $L1_0$ phases in ternary MnAlGa alloys — •Torsten Mix[1,2], Florian Bittner[1,3], Karl-Hartmut Müller[1], Ludwig Schultz[1,2,3], and Thomas George Woodcock[1] — [1]IFW Dresden, Institute for Metallic Materials, PO Box 270116, 01171 Dresden, Germany — [2]Department of Physics, TU Dresden, Dresden, Germany — [3]Institute for Materials Science, TU Dresden, Dresden, Germany

The $L1_0$ phases in the binary MnAl and MnGa systems are interesting candidates for rare earth free permanent magnets. The main drawbacks, are the high price of Ga and the poor resistance to decomposition at evelated temperature of the metastable $L1_0$ phase in binary MnAl. As the $L1_0$ phase in MnGa is thermodynamically stable, the formation of a ternary MnAlGa alloy is a promising approach to overcome these difficulties. Ternary alloys of the form $Mn_{55}Al_{45-x}Ga_x$ have been produced in the range 0 < x < 45. In alloys with 5 < x ≤ 9 after appropriate heat treatments, two different phases with the $L1_0$ structure can be made to coexist. One is stable as in the binary MnGa system, the other metastable as in binary MnAl. The magnetic properties of the ternary alloys are superior to those of the binary analogues. The thermal stability of the metastable phase is greatly improved by the addition of the small amount of Ga. Up to 700°C, the decomposition of the metastable phase is strongly suppressed. This allows longer processing time at higher temperatures, thus enabling new routes to produce rare earth free MnAl-based magnets to be envisaged.

15 min. break.

MA 56.7 Thu 16:45 HSZ 403

Impact of dislocations on coercivity in $L1_0$-MnAl — •Florian Bittner[1], Jens Freudenberger[1,2], Ludwig Schultz[1], and Thomas G. Woodcock[1] — [1]IFW Dresden, Institute for Metallic Materials, PO Box 270116, 01171 Dresden, Germany — [2]TU Bergakademie Freiberg, Institute of Materials Science, Gustav-Zeuner-Straße 5, 09599 Freiberg, Germany

Novel rare-earth free hard magnetic compounds are of growing interest due to the demand for permanent magnets with maximum energy densities between those of ferrites and rare earth magnets. The $L1_0$ ordered τ-MnAl is one candidate material for applications due to its promising intrinsic magnetic properties. Even though the anisotropy field is approximately 5 T, the coercivity achieved in bulk magnets is currently too low to reach its full potential. The reason for this discrepancy is caused by the microstructure of the material and the impact microstructural features on the magnetic properties. The coercivity of cold worked $Mn_{54}Al_{46}$ is remarkably increased from 0.02 T in the initial state to 0.29 T. Further annealing reduces coercivity while the microstructure remains unchanged within the resolution limit of the scanning electron microscope. Direct analysis of the quality of electron backscatter diffraction patterns was used to approximate the local dislocation density in the materials. The results showed significant evidence for different dislocation densities in the different metallurgical conditions. The conclusion that dislocations can act as pinning sites is also supported by the shape of the initial magnetisation curve and explained by local changes of the intrinsic magnetic properties.

MA 56.8 Thu 17:00 HSZ 403

A systematic study of RE lean $ThMn_{12}$-type phases — •Heike C. Herper, Olga Vekilova, and Olle Eriksson — Department of Physics and Astronomy, Uppsala University, Sweden

The demand for high performance magnets increases with the increasing usage of renewable energies, e.g. wind power plants. New magnets with lower content of rare earth (RE) compared to todays Fe-Nd-B magnets are needed. Rare earth lean systems such as $REFe_{12-x}M_x$ in the $ThMn_{12}$ structure are viewed as good alternatives because their RE content is much smaller and high anisotropies can be reached with interstitial nitrogen atoms. Even though these systems have been investigated for years systematic only few systematic studies exist which analyze the dependence of the magnetic properties on the concentration of the stabilizing element and the optimal N content in detail.

Here a series of $REFe_{12-x}M_xN_y$ phases with M = Ti, V and RE = Nd and Y has been systematically investigated with density functional theory methods in view of phase stability and magnetic properties depending on the amount of M and N. The geometry has been optimized using the VASP code and magnetic properties have been calculated within the full potential LMTO code RSPt [1] treating the 4f electron as a spin-polarized core electron.

[1] J. M. Wills et al, Full-Potential Electronic Structure Method, Vol. **167**, Springer series in solid state science (2010).

This work is supported by NOVAMAG (EU686056) and STandUP for energy (Sweden).

MA 56.9 Thu 17:15 HSZ 403

High-throughput density functional screening for permanent magnet materials — •Ingo Opahle — TU Darmstadt, Germany

High-throughput density functional calculations are used to search for candidates for new rare earth free permanent magnet materials. The key quantity here is the magneto-crystalline anisotropy energy (MAE), which sets an upper bound to the coercivity. The concept is explained at hand of the well-known Co-Pt system. It is shown that a considerably higher MAE than in the known L10 structure is possible, provided meta stable crystal structures can be stabilized, e.g by addition of a suitable element. Applications to further systems will be shown as well.

MA 56.10 Thu 17:30 HSZ 403

Magnetization behavior of hexagonal ferrites observed by *in-situ* Magnetic Force Microscopy — •Tim Helbig[1], Fabian Rhein[2], Volker Neu[3], Michael Krispin[2], and Oliver Gutfleisch[1] — [1]TU Darmstadt — [2]Siemens AG — [3]IFW Dresden

The sintering temperature of hexagonal ferrites with increasing partial Al substitution was systematically varied to obtain different microstructures. The grain size was found to range from a few hundred nanometers to several hundred micrometers. The grain size distribution depended on the Al content as well as the pre-milling and sintering conditions. Magnetic Force Microscopy (MFM) showed that the microstructure consists of a mixture of grains below the critical single-domain size, and larger grains with a multi-domain structure in the thermally demagnetized state (TDS). An *in-situ* MFM study was carried out depicting the magnetization from the TDS as well as the demagnetization under external magnetic field. From the surface domain contrast a magnetization was derived which quantitatively matches the global i.e. bulk magnetization obtained by SQUID magnetometry. The shape of the initial magnetization curve and the magnetization from the DC demagnetized state was correlated with the *in-situ* MFM data revealing a distinctly different magnetization behavior depending on grain size. Financial support by the German federal state of Hessen through its LOEWE program "RESPONSE" is gratefully acknowledged. The material development has been performed in BMBF funded project KomMa (03X3582).

MA 56.11 Thu 17:45 HSZ 403

Neutron depolarization imaging of magnetite in chiton teeth — •Marc Seifert[1,2], Michael Schulz[1,2], Georg Benka[2], Christian Pfleiderer[2], and Stuart Gilder[3] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technical University of Munich, D-85748 Garching, Germany — [2]Physics Department, Technical University of Munich, D-85748 Garching, Germany — [3]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität München, D-80539 Munich, Germany

Magnetite constitutes one of the most abundant magnetic minerals in the Earth's crust. In the single domain state, magnetite often carries the magnetic remanence in rocks due to its stable and strong magnetic remanence. Hence it is of keen interest to paleomagnetists who study the ancient magnetic field preserved in the rock record. The extremely small size range and vulnerability to oxidation of single domain magnetite makes synthetization and preservation virtually impossible. Consequently, most experimental work on magnetite under pressure is carried out on multidomain magnetite. The radula of the marine mollusc chiton (Polyplacophora) is one of the few natural sources of single domain magnetite. We have performed a comparative study on samples of chiton radula in a vibrating sample magnetometer (VSM) and with the newly evolving neutron depolarization imaging (NDI) technique. Despite a constant offset between the VSM and NDI data in the coercivity we find a good agreement between the two techniques.

MA 57: Multiferroics (DF and MA)

Chair: Joachim Hemberger

Time: Thursday 15:00–17:15 Location: WIL B321

MA 57.1 Thu 15:00 WIL B321

THz study of the magnon spectra of $BiFeO_3$ — •Dániel Gergely Farkas[1], Sándor Bordács[1], Dávid Szaller[1], Laur Peedu[2], Johan Viirok[2], Urmas Nagel[2], Toomas Rõõm[2], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, Hungary — [2]National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618 Tallinn, Estonia

Multiferroic materials with coexisting and strongly coupled magnetic and ferroelectric orders have attracted much interest due to the novel phenomena they possess, such as magnetoelectric effect [1] and directional dichroism [2]. Among these compounds $BiFeO_3$ has received special attention as it is one of the few known room-temperature multiferroics [3], which puts its technical applications within reach. Here we present an experimental study of the magnon excitations in single crystal samples of $BiFeO_3$. Using THz spectroscopy magnetic field dependence of the spin-wave frequencies are measured along all three high-symmetry axis up to 33T. This systematic study also allowed us to determine the electric and magnetic dipole strengths, i.e. the selection rules. In contrast to the previous theoretical models we found that the (111) plane of $BiFeO_3$ is isotropic and the magnetic field dependence of the excitation frequencies have hysteresis. References: [1] M. Tokunaga, et al., Nat. Commun. 6, 5878 (2015). [2] I. Kézsmárki, et al., Phys. Rev. Lett. 106, 057403 (2011). [3] J. Moreau, et al., J. Phys. Chem. Solids 32, 1315 (1971).

MA 57.2 Thu 15:15 WIL B321

Strain and electric-field mediated tuning of magnetism in self-assembled iron oxide nanoparticle - $BaTiO_3$ composites — •Liming Wang[1], Oleg Petracic[1], Emmanuel Kentzinger[1], Ulrich Rücker[1], Alexandros Koutsioumpas[2], Stefan Mattauch[2], Markus Schmitz[1], and Thomas Brückel[1,2] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich — [2]Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Jülich GmbH, Lichtenbergstr. 1, 85748 Garching, Germany

We report about the manipulation of magnetism of self-assembled iron oxide nanoparticle (NP) monolayers on top of $BaTiO_3$ (BTO) single crystals. Magnetoelectric coupling (MEC) as shown in both the magnetization and magneto-electric ac susceptibility (MEACS) measurements is observed. Both the magnetization and MEACS as function of temperature show abrupt jumps at the BTO phase transitions temperatures, which is attributed to strain-mediated MEC from the BTO onto the NPs. We find that a Ti sticking layer and an Au embedding layer play a crucial role to maximize the MEC effect. Moreover, using polarized neutron reflectivity (PNR) we observe a change of the in-depth magnetic scattering length density upon changing an applied electric field. Grazing incident small angle X-ray scattering (GISAXS) and scanning electron microscopy (SEM) confirm a hexagonal close-packed supercrystalline order of the NPs.

MA 57.3 Thu 15:30 WIL B321

Single domain multiferroic $BiFeO_3$ films — •Chang-Yang Kuo[1], Zhiwei Hu[1], Jan-Chi Yang[1], Tun-Wen Pi[2], Stefano Agrestini[1], Kai Chen[3], Philippe Ohresser[3], Arata Tanaka[4], Liu Hao Tjeng[1], and Ying-Hao Chu[5] — [1]MPI-CPfS, Dresden, Germany — [2]NSRRC, Taiwan — [3]Synchrotron SOLEIL, France — [4]Hiroshima University, Japan — [5]National Chiao Tung University, Taiwan

The strong coupling between antiferromagnetism and ferroelectricity at room temperature found in $BiFeO_3$ generates high expectations for the design of technological devices. However, the multi-domain nature of the material tends to nullify the properties of interest and complicates the thorough understanding of the mechanisms involved. Here we report the realization of a $BiFeO_3$ thin film which shows single domain behavior in both its magnetism and ferroelectricity: the entire film has its antiferromagnetic axis aligned along the crystallographic b-axis and its ferroelectric polarization along the c-axis. This allows us to reveal that the canted and net ferromagnetic moment due to the Dzyaloshinskii-Moriya interaction is parallel to the a-axis. Furthermore, by making a Co/$BiFeO_3$ heterostructure, we successfully demonstrate that the ferromagnetic moment of the Co metal film couples directly to the canted ferromagnetic moment of $BiFeO_3$. The realization of the single-domain multiferroic $BiFeO_3$ films thus provides new insights into the fundamental interactions in this functional material and opens a promising path for the engineering of novel functional devices[1]. [1]C.Y. Kuo *et al.* Nature Communications, 7, 12712 (2016).

MA 57.4 Thu 15:45 WIL B321

New multiferroic materials - oxyhalides & orthotellurates — •A. C. Komarek[1], L. Zhao[1], H. Guo[1], M. T. Fernández-Díaz[2], W. Schmidt[3], and L. H. Tjeng[1] — [1]Max-Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, D-01187 Dresden, Germany — [2]Institut Laue-Langevin, 71 Avenue des Martyrs, F-38042 Grenoble Cedex 9, France — [3]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at ILL, 71 avenue des Martyrs, F-38042 Grenoble Cedex 9, France

Magnetoelectric multiferroics have attracted considerable attention in the past years due to their possible application in future devices. Especially certain spiral magnetic structures are often responsible for the cross-coupling between magnetism and ferroelectricity in these materials. So far multiferroicity has been found mainly in oxide materials. Here, we report the observation of multiferroicity in two other interesting classes of transition metal compounds: First, we found spin-induced multiferroicity with high critical temperature in a transition metal oxyhalide (Cu_2OCl_2 [1]), and second, we also observed multiferroic properties in a transition metal orthotellurate with a complex magnetic structure (Mn_3TeO_6 [1]).

—**References**— [1] L. Zhao, M. T. Fernández-Díaz, L. H. Tjeng and A. C. Komarek, Science Advances, **2**, e1600353 (2016). [2] L. Zhao, Z. Hu, C.-Y. Kuo, T.-W. Pi, M.-K. Wu, L. H. Tjeng and A. C. Komarek, Phys. Status Solidi RRL **9**, 730 (2015).

15 min. break

MA 57.5 Thu 16:15 WIL B321

Magneto-optic and electro-optic effects in multiferroic thin films — •Simon Wisotzki, Liane Brandt, Diana Rata, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale)

Jia *et al.* [1] proposed a magneto-electric coupling effect for ferromagnetic (FM)/ferroelectric(FE) composites. This phenomenon is purely charge-mediated and accompanied by the build-up of an interfacial spiral spin density. Depending on the FE polarization state in a FM/FE composite, the surface spiral spin density induced in the FM layer should change direction. For a suitable sample geometry, one can expect the reversal of the out-of-plane component of the magnetization at the FM/FE interface, with this effect decaying across the spin diffusion length. We utilize a setup that is sensitive to minute changes ($<10^{-6}$ rad) of the polarization state of reflected light from the multiferroic composite. In our experiments, magneto-optic effects (reflection on FM surface) as well as electro-optic effects (caused by the FE layer) may contribute to the measured change of the polarization state upon reflection. In a series of experiments on thin film multiferroic capacitors consisting of FM/FE/FM, we try to distinguish between the two effects and identify a possible magneto-electric contribution as suggested in [1]. The investigated samples include epitaxial LSMO/PZT/LSMO and LSMO/PZT structures with polycrystalline FM top electrodes.

[1] C.-L. Jia *et al.*, *Phys. Rev. B* **90**, 054423 (2014)

MA 57.6 Thu 16:30 WIL B321

Collective spin excitations in polar ferrimagnet $(Fe,Zn)_2Mo_3O_8$ — •Krisztián Szász[1], Dávid Szaller[1], Urmas Nagel[2], Toomas Rõõm[2], Sándor Bordács[1], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary — [2]National Institute of Chemical Physics and Biophysics, 12618 Tallinn, Estonia

In this work the magnetic excitations are investigated in Zn-doped hexagonal polar $Fe_2Mo_3O_8$ crystal using terahertz spectroscopy. This material is a promising candidate in realizing new generation electronic devices utilizing its giant magnetoelectric effect, i.e. high jump is observed in the polarization when the antiferromagnetic-ferrimagnetic spin-flop transition occurs. The different magnetic phases can be controlled by doping without losing the huge magnetoelectric effect. Microscopically, the Zn-doping fills the tetrahedral Fe sublattice while the octahedral Fe sites remain intact.

Our purpose is to understand the magnetic ground state which is still unclear. Furthermore, from the magnetic field dependence of the magnon modes we aim to deduce the most important exchange and anisotropy parameters to construct a spin model of $Fe_2Mo_3O_8$.

MA 57.7 Thu 16:45 WIL B321

Magnetic excitations in multiferroic $GdMn_2O_5$ — •Sergey Poghosyan and Sergey Artykhin — Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

RMn_2O_5 compounds recently attracted attention due to non-collinear states and unconventional excitations. YMn_2O_5 with non-magnetic rare earth (RE) shows incommensurate spiral state with spins in the neighbouring chains aligned at 90-degrees to each other [1]. RE ions with unquenched angular momentum enable the control of polarization by magnetic field in the multiferroic materials, such as $TbMn_2O_5$ [2]. $GdMn_2O_5$ with magnetic rare earth in S=7/2, L=0 state, exhibits a spiral state below 40 K, that concedes to a commensurate state below $\sim$ 30K. The latter hosts large magnetically-induced polarization of 3600 $\mu C/m^2$ induced via Heisenberg exchange striction mechanism. This polarization changes by 5000 $\mu C/m^2$ under the external magnetic field [3]. Here we corroborate THz magnetoabsorption data with the microscopic modelling. The magnetic excitations are calculated using model Hamiltonian with parameters extracted from ab-initio simulations. The resultant magnon spectrum is rather counterintuitive and complex, thus providing new insights on design principles for materials with strong magnetoelectric couplings.

[1] J.-H. Kim et al., Phys. Rev. Lett. **107**, 097401 (2011).
[2] N. Hur et al., Nature **429**, 392 (2004).
[3] N. Lee et al., Phys. Rev. Lett. **110**, 137203 (2013).

MA 57.8 Thu 17:00 WIL B321

Simulation and investigation of polarization kinetics in polycrystalline ferroelectrics. — •Ruben Khachaturyan — Technische Universität Darmstadt, Department of Materials Modeling, 64295 Darmstadt, Stephanstr. 5

The understanding of polarization dynamics over a wide time scale plays a crucial role in a vast range of applications, from non-volatile memories (FeRAM) and sensors to fuel injection applications.

It was established that polarization process under applied voltage develops simultaneously in different parts of a material with different switching times [1]. As switching time is strongly field dependent [2] it was suggested that local switching time distribution is caused by local electrical field distribution [3-5].

There is currently no statistical concept that accounts for spatial correlations of local polarizations and fields during polarization switching in a ferroelectric polycrystalline material.

The main purpose of the work is to simulate dynamics of polarization switching in a polycrystalline material under applied electric field. The data extracted from the simulations, such as field and polarization distributions and their correlations at different times, provide necessary information to study influence of the local field distribution on local switching processes.

MA 58: Transport: Spintronics, Spincalorics and Magnetotransport (jointly with DS, HL, MA)

Time: Friday 9:30–11:30 Location: HSZ 03

MA 58.1 Fri 9:30 HSZ 03

Search for magneto-hydrodynamics in the delafossite metals $PdCoO_2$ and $PtCoO_2$ — •Nabhanila Nandi[1], Pallavi Kushwaha[1], Seunghyun Khim[1], Philip J.W. Moll[1], Burkhard Schmidt[1], Thomas Scaffidi[2], Markus König[1], and Andrew P. Mackenzie[1,3] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Scottish Universities Physics Alliance, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, United Kingdom

Electrical resistance is conventionally determined by the momentum-relaxing scattering of electrons by the host solid and its excitations. Hydrodynamic fluid flow through channels, in contrast, is determined by geometrical factors, boundary scattering and the viscosity of the fluid, which is governed by momentum-conserving internal collisions. In almost all known materials, however, the signatures of viscosity in electron flow cannot be resolved, because the rate of momentum-relaxing collisions dominates that of the momentum-conserving ones that give the viscous term. In previously published work, we reported experimental evidence that there is a regime in restricted channels of the ultra-pure two-dimensional delafossite metal $PdCoO_2$ in which the resistance has a large viscous contribution. In this talk I will report on our current work in which we extend our experiments to magneto-hydrodynamics, discussing data both from $PdCoO_2$ and a second delafossite metal, $PtCoO_2$.

MA 58.2 Fri 9:45 HSZ 03

Fe_3O_4 thin films: controlling and manipulating an elusive quantum material — •xionghua liu, chun-fu chang, aurora diana rata, alexander christoph komarek, and liu hao tjeng — Max Planck Institute for Chemical Physics of Solids, Nöthnitzerstr. 40, 01187 Dresden, Germany

Fe_3O_4 (magnetite) is one of the most elusive quantum materials and at the same time one of the most studied transition metal oxide materials for thin film applications. The theoretically expected half-metallic behavior generates high expectations that it can be used in spintronic devices. Yet, despite the tremendous amount of work devoted to preparing thin films, the enigmatic first order metal-insulator transition and the hall mark of magnetite known as the Verwey transition, is in thin films extremely broad and occurs at substantially lower temperatures as compared to that in high quality bulk single crystals.

In this work, we investigate systematically the effect of oxygen stoichiometry, thickness, strain, and microstructure on the Verwey transition in epitaxial Fe_3O_4 thin films on a variety of substrates. We have been able to determine the factors that affect negatively the Verwey transition in thin films. We have succeeded in finding and making a particular class of substrates that allows the growth of magnetite thin films with the Verwey transition as sharp as in the bulk. Moreover, we are now able to tune the transition temperature and, using tensile strain, increase it to substantially higher values than in the bulk.

MA 58.3 Fri 10:00 HSZ 03

Spin-switching via quantum dot spin valves — •Niklas M. Gergs[1], Scott A. Bender[1], Rembert A. Duine[1,2], and Dirk Schuricht[1] — [1]Institute for Theoretical Physics, Utrecht University, Utrecht, The Netherlands — [2]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

We theoretically investigate a spin-valve transistor setup, ie, correlated transport through a quantum dot positioned between two spin-polarised nano magnets. This causes the dynamical generation of a magnetic field on the dot even in the absence of external fields [1].

Here we consider the back action of the quantum dot onto the attached nano magnets via exerted spin torques. This may be used to switch the nano magnets reliably from a parallel to an anti-parallel alignment and vice versa. All operations are done in the Coulomb-blockade regime of the quantum dot, so that the charge transport through the setup is strongly suppressed.

[1] M. Braun, J. König, J. Martinek, Phys. Rev. B 70, 195345 (2004)

MA 58.4 Fri 10:15 HSZ 03

Strong non-equilibrium effects in spin torque systems — •Tim Ludwig[1], Igor S. Burmistrov[2,3], Yuval Gefen[4], and Alexander Shnirman[1] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]L.D. Landau Institute for Theoretical Physics RAS, Kosygina street 2, 119334 Moscow, Russia — [3]Laboratory for Condensed Matter Physics, National Research University Higher School of Economics, 101000 Moscow, Russia — [4]Department of Condensed Matter Physics, Weizmann Institute of Science, 76100 Rehovot, Israel

We consider a problem of persistent magnetization precession in a single domain ferromagnetic nano particle under the driving by the spin-transfer torque [1]. We find that the adjustment of the electronic distribution function in the particle renders this state unstable. Instead, abrupt switching of the spin orientation is predicted upon increase of the spin-transfer torque current. On the technical level, we derive an effective action of the type of Ambegaokar-Eckern-Schön action for the coupled dynamics of magnetization (gauge group SU(2)) and voltage (gauge group U(1)).

[1] T. Ludwig, I. S. Burmistrov, Y. Gefen, and A. Shnirman, arXiv:1610.09944 (2016)

MA 58.5 Fri 10:30 HSZ 03

Spin-charge coupled dynamics driven by a time-dependent magnetization — •Sebastian Tölle[1], Ulrich Eckern[1], and Cosimo Gorini[2] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany

The spin-charge coupled dynamics in a thin, magnetized metallic system are investigated. The effective driving force acting on the charge carriers is generated by a dynamical magnetic texture, which can be induced, e.g., by a magnetic material in contact with a normal-metal system. We consider a general inversion-asymmetric substrate/normal-metal/magnet structure, which, by specifying the precise nature of each layer, can mimick various experimentally employed setups. Inversion symmetry breaking gives rise to an effective Rashba spin-orbit interaction. We derive general spin-charge kinetic equations which show that such spin-orbit interaction, together with anisotropic Elliott-Yafet spin relaxation, yields significant corrections to the magnetization-induced dynamics. To highlight their physical meaning, the spin pumping configuration of typical experimental setups is analyzed in detail. In the two-dimensional limit the build-up of a DC voltage is dominated by the spin galvanic (inverse Edelstein) effect. A measuring scheme that could isolate this contribution is discussed.

MA 58.6 Fri 10:45 HSZ 03

Emergent magnetic ordering in transition metal atomic contacts — •Martin Keller, Florian Strigl, Elke Scheer und Torsten Pietsch — Department of Physics, University of Konstanz, 78457 Konstanz, Germany

MD simulations and DFT calculations predict the development of local magnetic order at reduced dimensions in some paramagnetic transition metals (Pt, Pd, Ir), especially in atomic configurations [1,2,3]. This unusual property allows us to investigate the influence of the local magnetic properties on the conductance of atomic contacts without the effect of magnetic leads. Therefore atomic contacts of these metals are a model system to understand the origin of magnetoconductance and the role of spin-polarization of the conduction electrons. Herein we discuss recent results of Pt, Pd and Ir in the context of a microscopic model that successfully describes the observed magnetoconductance signature in these atomic contacts and chains [4]. Additionally, electronic transport spectroscopy is used to evaluate magnetic excitations in the electronic system of the contact, i.e. the presence of i) a zero-bias anomaly which is described by Kondo physics and ii) conductance fluctuations in the atomic contact, which indicate the formation of a magnetically ordered state. We will compare the three transition metals with respect to their different electronic structure and the role of spin-orbit coupling in the contacts.

[1] Phys. Rev. Lett. 92, 057201 (2004)
[2] Phys. Rev. B 78, 014423 (2008)
[3] Phys. Rev. B 81, 054433 (2010)
[4] Nature Comm. 6, 6172 (2015); Phys. Rev. B 94, 144431 (2016)

MA 58.7 Fri 11:00 HSZ 03

Electron transport through the helical systems: chiral magnetoresistance effect — •Volodymyr V. Maslyuk, Rafael Gutiérrez, and Gianaurelio Cuniberti — Institute for Material Science and Max Bergmann Center for Biomaterials, Dresden University of Technology, Hallwachstr. 3, 01069 Dresden, Germany

Recently, the chirality-induced spin selectivity (CISS) effect [1] has been discovered in which electron transport through systems with helical symmetry shows the different transmission for the electrons with different spin-polarizations. In this work, we show that CISS can be utilized in the new class of magnetic field sensors via novel chiral magnetoresistance effect (CMR) [2]. We present a theoretical investigation of the electron transport through the poly-GLY in helical form placed between one magnetic and one nonmagnetic leads by using the DFT and NEGF approach. We obtain that MR of the order 2

[1] Göhler B., Hamelbeck V., Markus T. Z., Kettner M., Hanne G. F., Vager Z., Naaman R., and Zacharias H., Science 331, 894 (2011)
[2] Kiran V., Mathew S.P., Cohen S.R., Delgado I.H., Lacour J., Naaman R., Adv. Mater. 28, 1957 (2016)

MA 58.8 Fri 11:15 HSZ 03

A Landauer-Büttiker approach for hyperfine mediated electronic transport in the integer quantum Hall regime — •Aniket Singha[1], M. Hamzah Fauzi[2], Yoshiro Hirayama[2], and Bhaskaran Muralidharan[1] — [1]Department of Electrical Engineering, IIT Bombay, Powai, Mumbai-400076, India — [2]Graduate School of Science, Tohoku University, Aoba-ku, Sendai-980-8578, Japan

The interplay of spin-polarized electronic edge states with the dynamics of host nuclei in quantum Hall systems presents rich and non-trivial transport physics. Here, we develop a Landauer-Büttiker approach to understand various experimental features observed in integer quantum Hall set ups featuring quantum point contacts. Such approach entails a phenomenological description of spin resolved inter-edge scattering induced via hyperfine assisted electron-nuclear spin flip-flop processes along with a self consistent simulation framework between the nuclear spin dynamics and edge state electronic transport in order to gain insights into the nuclear polarization effects on electronic transport vice-versa. In particular, we show that the hysteresis noted experimentally in the conductance-voltage trace as well as in the resistively detected NMR lineshape results from a lack of quasi-equilibrium between electronic transport and nuclear polarization evolution. In addition, we present circuit models to further facilitate a clear understanding of the electronic transport processes occurring near the quantum point contact.

MA 59: Topological Insulators II (jointly with DS, HL, O, TT)

Time: Friday 9:30–11:30 Location: HSZ 04

MA 59.1 Fri 9:30 HSZ 04

Laser induced DC photocurrents in a Topological Insulator thin film — •Nina Meyer[1], Thomas Schumann[1], Eva Schmoranzerová[2], Helena Reichlová[3], Gregor Mussler[4], Petr Nemec[2], Detlev Grützmacher[4], and Markus Münzenberg[1] — [1]Institute of Physics, Ernst-Moritz-Arndt University, Greifswald, Germany — [2]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic — [3]Institute of Physics ASCR v.v.i., Prague, Czech Republic — [4]Inst. for Semiconductor Nanoelectronics, Peter Grünberg Institute-9, Forschungszentrum Jülich, Germany

Recent experiments indicate that the optical excitation of spin-polarized surface states of topological insulators (TI) can launch electron currents along the surface. The current's direction can be controlled by varying the polarization of the driving light. We investigated if the spin-polarized current can be optimized by changing the angle of incident and the position of the laser spot on the sample. The used TI (Bi, Sb)$_2$Te$_3$ thin films with a thickness of 20 nm were structured to Hall bar devices. We successfully generated a photocurrent by illuminating the TI thin films with laser light whose polarization changes periodically. Analyzing the contributions of the photocurrent we detected a spin-polarized current. We found that the spin-polarized current is near-constant for angles of incident between 35° and 65° and that the position of the laser spot on the sample affects the spin-polarized current more than the angle of incident.

We acknowledge funding through DFG priority program SPP "Topological Insulators" and DAAD PPP Czech Republic "FemtomagTopo".

MA 59.2 Fri 9:45 HSZ 04

Origin of Dirac cones in projected band-gaps: W(110) —

•Gustav Bihlmayer[1], Andrei Varykhalov[2], Oliver Rader[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut (PGI-1) & Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany

Angle-resolved photoemission experiments show the existence of band-crossings with linear dispersion - often called Dirac-cones - in the projected band gaps of W(110) and Au-covered W(110). While previous studies focused on a Dirac-cone at the $\overline{\Gamma}$-point and the possible connection to the topology of the bulk band-structure [1], we analyze the band-crossings in the metallic regions of the band structure along the $\overline{\Gamma - N}$ line of the Brillouin zone where such a term is not well defined. Based on density functional theory calculations we elucidate the origin of these crossings and find three necessary ingredients for the evolution of such structures: (i) the crossing of two surface states of different symmetry (ii) the presence of spin-orbit coupling that leads to a Rashba-type splitting of these states and (iii) mirror symmetry that protects the crossing point of the bands [2]. We discuss the relation of this mirror symmetry to the properties of topological crystalline insulators, which show similar Dirac-cones in global band-gaps.
Financial support of the DFG (SPP 1666) is gratefully acknowledged.
[1] D. Thonig et al., Phys. Rev. B. **94**, 155132 (2016).
[2] A. Varykhalov et al., submitted (2016).

MA 59.3 Fri 10:00 HSZ 04

Chiral anomaly and negative longitudinal magnetoresistance in Weyl semimetals within a Boltzmann approach — •Annika Johansson[1,2], Julia Weiner[2], Jürgen Henk[2], and Ingrid Mertig[2,1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

In Weyl semimetals, the application of non-orthogonal electric and magnetic fields gives rise to the chiral anomaly. The breaking of the chiral symmetry results in nonconservation of chiral charge [1-3]. Phenomena related to the chiral anomaly are the anomalous Hall effect, the chiral magnetic effect, and the negative longitudinal magnetoresistance (NLMR).

We consider the chiral anomaly in Weyl semimetals for small magnetic fields [4]. Using a semiclassical Boltzmann approach, we investigate the increase of the longitudinal charge conductivity related to the chiral anomaly. The longitudinal magnetoresistance is calculated for model systems including anisotropic and energy dependent momentum relaxation times. The energy dependence of the scattering processes has a pronounced effect on the magnitude of the NLMR, whereas the influence of the relaxation time anisotropy is negligible.

[1] S. Adler, Phys. Rev. **177**, 2426 (1969)
[2] J. S. Bell and R. Jackiw, Nuovo Cimento A **60**, 47 (1969)
[3] H. B. Nielsen and M. Ninomiya, Phys. Lett. B **130**, 389 (1983)
[4] D. T. Son and B. Z. Spivak, Phys. Rev. B **88**, 104412 (2013)

MA 59.4 Fri 10:15 HSZ 04

Topological Weyl semimetals in the chiral antiferromagnetic materials Mn3Ge and Mn3Sn — •Hao Yang[1,2], Yan Sun[2], Yang Zhang[2,3], Wu-Jun Shi[2], Stuart S. P. Parkin[1], and Binghai Yan[2] — [1]Max Planck Institute of Microstructure Physics, 06120 Halle(Saale), Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany

It was recently found in experiment that Mn3Sn and Mn3Ge exhibit a strong anomalous Hall effect at room temperature, provoking us to explore their electronic structures for topological properties. By ab initio band structure calculations, we have observed the existence of multiple Weyl points in the bulk and corresponding Fermi arcs on the surface, predicting antiferromagnetic Weyl semimetals in the titled compounds [1]. Here the chiral antiferromagnetism in the Kagome-type lattice structure is essential to determine the positions and numbers of Weyl points. Our work further reveals a new guiding principle to search for magnetic Weyl semimetals among materials that exhibit a strong anomalous Hall effect. [1] H Yang, Y Sun, Y Zhang et.al., arXiv preprint arXiv:1608.03404 (2016)

MA 59.5 Fri 10:30 HSZ 04

Strong intrinsic spin Hall effect in the TaAs-family of Weyl semimetals — •Yan Sun[1], Yang Zhang[1,2], Claudia Felser[1], and Binghai Yan[1,3] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [3]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden,Germany

Since their birth topological insulators have been expected to be ideal spintronic materials due to the spin currents carried by the surface states with spin-momentum locking . However, the bulk doping problem still remains to be an obstacle that hinders such application. In this work, we predict that a newly discovered family of topological materials, the Weyl semimetals, exhibits large intrinsic spin Hall effects that can be utilized to generate and detect spin currents[1]. Our ab-initio calculations reveal large spin Hall conductivity that is comparable to that of 4d and 5d transition metals. The spin Hall effect originates intrinsically from the bulk band structure of Weyl semimetals that exhibits large Berry curvature and spin-orbit coupling, naturally avoiding the bulk carrier problem in the topological insulators. Our work not only paves a way to employ Weyl semimetals in spintronics, but also proposes a new guideline to search for spin Hall effect materials in various topological materials.

[1] Yan Sun, Yang Zhang, Claudia Felser, and Binghai Yan, Phy. Rew. Lett. 117, 146403 (2016)

MA 59.6 Fri 10:45 HSZ 04

Dzyaloshinskii-Moriya interaction in graphene nanoribbons on topological insulator substrates — •Farideh Hajiheidari[1], Wei Zhang[2], Yan Li[3], and Riccardo Mazzarello[1,4] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany — [2]Center for Advancing Materials Performance from the Nanoscale, State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, China — [3]Institute IEK-6, Forschungszentrum Jülich, Germany — [4]JARA-FIT and JARA-HPC, RWTH Aachen University, Aachen, Germany

The three-dimensional topological insulators (TIs) realize an unconventional electronic phase originating from time-reversal symmetry and strong spin-orbit coupling. These class of material have conducting surface states in the bulk band gap. The surface states strongly affect the coupling between the magnetic impurities deposited on the surface. In this work, we present a first-principles investigation of zigzag graphene nanoribbons (GNRs) on the (111) surface of the topological insulator Sb2Te3. We consider unpassivated edges, which bind strongly to the substrate. In spite of the strong interaction between the edge atoms and the TI surface, the edge magnetism is preserved. However, the spins at the GNR edges are twisted due to the Dzyaloshinskii-Moriya interaction (DMI) which appears in magnetic systems that lack inversion symmetry and exhibit strong SOC. This results in a finite net magnetization due to the deviation from the perfect AFM coupling, and leads to a shift of the Dirac point of the surface state of the TI and can even open a small gap depending on its direction.

MA 59.7 Fri 11:00 HSZ 04

Is SmB$_6$ a failed superconductor — •Onur Erten — Max Planck Institute for the Physics of Complex Systems, Dresden

The classic theory of superfluids and superconductors is founded on London's idea of "wavefunction rigidity", in which gradients of the phase of the ground-state condensate carry the superflow. However, the study of neutral superfluids teaches that a stable superflow also requires the topological quantization of circulation: when this is absent, as in the case of He-3A, the superflow is unstable. Here, we generalize this idea to charged superfluids, introducing the concept of a failed superconductor in which a higher order parameter manifold topologically destablizes vortices, causing a rapid decay of supercurrents, giving rise to a novel diamagnetic insulator. We apply this idea to the case of SmB$_6$, arguing that the observation of a gapless diamagnetic Fermi surface within an insulating bulk can be understood as a failed odd-frequency superconductor. Our results enable us to understand the linear specific heat of SmB$_6$ in terms of a neutral Majorana Fermi surface and lead us to predict that in low fields, SmB$_6$ will develop a Meissner effect.

MA 59.8 Fri 11:15 HSZ 04

Instability of the topologically protected surface state inBi_2Se_3 upon deposition of gold — •Andrey Polyakov[1], Holger L. Meyerheim[1], Christian Tusche[2], Daryl E. Crozier[3], and Arthur Ernst[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany, Germany — [3]Department of Physics, Simon Fraser University Burnaby, BC Canada, V5A 1S6

We present an experimental and theoretical analysis of the stability of the Topological surface state (TSS) in Bi_2Se_3 upon sub-monolayer deposition of Au. Extended x-ray absorption fine structure experiments provide clear evidence that Au -when deposited on the (0001) surface kept at 160 K- substitutes Bi atoms within the first quintuple layer. This goes in parallel with the dramatic weakening of the spectral density of the TSS as observed by angular resolved photoemission. In accordance with first-principles calculations, Au in Bi substitutional sites within the first QL creates a d-type resonant state near E_F, which hybridizes with the TI bands and substantially modifies its surface electronic structure. According to the model of Black-Schaffer et al. [1] a bulk-surface interaction is a prerequisite for the gap opening, since the TSS is not protected by scattering processes involving bulk three-dimensional states. References: [1] A. M. Black-Schaffer and A. V. Balatsky, Phys. Rev. B 86, 115433 (2012). Acknowedgements: Work supported by SPP 1666. Work at the APS is supported by the U.S. DOE under Contract No. DE-AC02-06CH11357.

MA 60: Magnetic Materials: Applications and Multielement Bulk Materials

Time: Friday 9:30–12:00 Location: HSZ 101

MA 60.1 Fri 9:30 HSZ 101

Magnetic e-skin enables both touch and non-touching sensitivities — •J. Ge, X. Wang, G. S. Canon Bermudez, J. Fassbender, and D. Makarov — Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany

Humans can interact with unstructured surroundings precisely with the aid of ears, eyes, and skin. Ears and eyes help humans interact with surrounding objects though a non-touching mode, while human skin provides the touch feeling for humans to sense the temperature of objects, strain and pressure on skin, friction for holding objects, among others. Interest of realizing both touch and non-touching sensing functions of humans is motivated by the promise of creating advanced humanoid robots, biomedical prostheses, surgical electronic gloves and wearable health monitoring devices [1, 2]. Herein we present a magnetic skin that not only is sensitive to pressure, flexion, and strain, but also has the ability to detect the position and movement of magnetic objects in a non-touching sensing mode. The magnetic skin is a stack of a wrinkle GMR sensor layer and a pyramid-structured magnetic foil. The GMR sensor enables the sensing of the movement of remote magnetic objects (non-touching), and distance change between GMR sensor and magnetic foil caused by mechanical deformation make the magnetic skin be sensitive to pressure, stretch and flexion (touch mode). This magnetic skin will possess great potential application in future intelligent products.

1. Z. Q. Ma et al. Science 333, 830-831, (2011). 2. Z. A. Bao et al. Adv. Mater. 25, 5997-6037, (2013).

MA 60.2 Fri 9:45 HSZ 101

Valence state of Sm in Sm-substituted EuO — •Andreas Reisner, Steffen Wirth, Simone G. Altendorf, and Liu Hao Tjeng — Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187, Dresden, Germany

Europium monoxide is a ferromagnetic semiconductor with a Curie temperature of 69 K. It has the rocksalt crystal structure with a lattice constant of 5.14 Å and the Eu is in the stable high-spin divalent state. SmO on the other hand, is a non-magnetic metallic oxide. It has also the rocksalt crystal structure and the lattice constant is 4.94 Å. Interestingly, the Sm is presumably in a mix-valent state (2.9+) as argued from lattice constant considerations [J. M. Leger et *al*., Inorg. Chem. 19, 2252 (1980); G. Krill et *al*. Solid State Commun. 33, 351 (1980)]. The question now arises what the valence of the Sm will be if it is inserted in the EuO crystal. Considering the larger lattice constant of EuO as compared to SmO, one may expect that the Sm in EuO will have enough room to stabilize even the divalent (and non-magnetic) charge state [D. Kasinathan et *al*., Phys. Rev. B 91, 195127 (2015)].

We have grown thin films of $Sm_xEu_{1-x}O$ using reactive molecular beam epitaxy. Structural analysis verifies the incorporation of Sm into the EuO crystal up to high doping levels of 17 at.%. We will present our *in situ* x-ray photoelectron spectroscopy study as well as our *ex situ* magnetization measurements to unveil the valence of Sm inserted in EuO.

MA 60.3 Fri 10:00 HSZ 101

Interplay of localization and magnetism in (Ga,Mn)As and (In,Mn)As — •Ye Yuan[1], Maciej Sawicki[2], Tomasz Dietl[2,3,4], Manfred Helm[1], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Institute of Physics, Warsaw, Poland — [3]Faculty of Physics, University of Warsaw, Warsaw, Poland — [4]WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan

We examine the role of localization on the hole-mediated ferromagnetism in dilute ferromagnetic semiconductors by combining results of electrical and magnetic studies for Mn-implanted GaAs and InAs. In both materials upon increasing the Mn concentration, a change from an insulating (hopping) regime of conductivity to a metallic-like is accompanied by a gradual build-up of a long-range magnetic coupling and a monotonic increase of the Curie temperature. For the least conducting sample no (global) Curie temperature can be identified, although the observed slow dynamics (superparamagnetic-like) confirms the presence of a ferromagnetic coupling acting only over limited (mesoscopic) distances. Our findings strongly advocate for the heterogeneous model of electronic states at the localization boundary and point to the crucial role of weakly localized holes in mediating efficient spin-spin interactions between diluted spins even on the insulator side of the metal-to-insulator transition. This constitutes a new experimental support for the suggestion that larger p-d coupling results in higher values of TC only in the regime, where hole localization effects are not crucial.

MA 60.4 Fri 10:15 HSZ 101

Electronic and magnetic properties of the 2H-NbS_2 intercalated by $3d$ transition elements — •Sergiy Mankovsky[1], Svitlana Polesya[1], Hubert Ebert[1], and Wolfgang Bensch[2] — [1]Dept. Chemie, Ludwig-Maximilians-Universität München, 81377 München, Germany — [2]Inst. für Anorgan. Chemie, Universität Kiel, 24098 Kiel, Germany

The electronic structure and magnetic properties of the 2H-NbS_2 compound intercalated by $3d$ transition elements, have been investigated by means of the Korringa-Kohn-Rostoker (KKR) method. Magnetic torque calculations demonstrate an easy plane magneto-crystalline anisotropy (MCA) for the $Cr_{1/3}NbS_2$ and $Mn_{1/3}NbS_2$ compounds for their ground state at $T = 0$ K. Going from the Cr and Mn to the Fe intercalated system, the modification of the electronic structure results in a change of the uniaxial MCA from the in-plane to the out-of-plane anisotropy. It is shown, that for $Cr_{1/3}NbS_2$ and $Mn_{1/3}NbS_2$ the in-plane MCA and Dzyaloshinskii-Moriya interactions give rise to a helimagnetic structure along the hexagonal c axis; in line with experiment. The negative exchange interactions in the $Fe_{1/3}NbS_2$ compound results in a non-collinear frustrated magnetic structure if the MCA is not taken into account. However, a strong MCA along the hexagonal c axis leads – as observed experimentally – to a magnetic ordering referred to as ordering of the third kind.

MA 60.5 Fri 10:30 HSZ 101

Thermal and thermoelectric high-magnetic-field study of the multiband superconductor FeSe — •Stevan Arsenijević[1], Tatsuya Watashige[2], Lars Opherden[1], Shigeru Kasahara[2], Yoshifumi Tokiwa[2], Yuichi Kasahara[2], Takasada Shibauchi[3], Hilbert von Löhneysen[4], Jochen Wosnitza[1], and Yuji Matsuda[2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Department of Physics, Kyoto University, Kyoto 606-8502, Japan — [3]Department of Advanced Materials Science, University of Tokyo, Chiba 277-8561, Japan — [4]Physikalisches Institut, Karlsruhe Institut für Technologie, 76131 Karlsruhe, Germany

We explored the high-magnetic-field behavior of the thermoelectric and thermal-transport coefficients to probe the quasiparticle excitations in the normal and superconducting phase of FeSe. The small and compensated thermoelectric coefficients increase with decreasing temperature (T) due to the T-dependent increase of the charge-carrier mobility and the dominant role of the small hole Fermi-surface pocket. The measured longitudinal and transverse thermal conductivities imply that a highly anisotropic small superconducting gap forms at the electron pocket whereas an isotropic and larger gap forms at the hole pocket. Below 1 K, both thermal conductivities exhibit anomalies at the upper critical field, H_{c2}, and at a constant field H^* around 14 T. These results support the existence of a distinct field-induced superconducting phase above H^* which emerges with a presumed large spin-imbalance of the hole Fermi-surface pocket.

MA 60.6 Fri 10:45 HSZ 101

Epitaxial thin films of Sr_2MnIrO_6 double perovskites — •Supratik Dasgupta, Philipp Komissinskiy, Hongbin Zhang, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

We present our studies of highly crystalline epitaxial thin films of a 3*d*-5*d* double perovskite Sr_2MnIrO_6 grown by pulsed laser deposition. In this compound, the orbital degeneracy between the t_{2g} and e_g electron states is lifted with the crystal field of the heavy Ir^{4+} cation. Moreover, the t_{2g} levels are split into low-energy $J = 3/2$ and high-energy $J = 1/2$ states due to the strong spin-orbital coupling, resulting in exotic ground states observed previously in other perovskite iridates [1]. The compressively (tensile) strained Sr_2MnIrO_6 films were grown onto LSAT ($SrTiO_3$ and $DyScO_3$) single crystalline substrates. Magnetic measurements of the Sr_2MnIrO_6 films grown on $SrTiO_3$ reveal T_c =110 K. The observed magnetization values of $0.4\,\mu_B$/f.u. at 5 K can be explained with a Mn antiferromagnetic coupling plus a spin canting due to the tetragonal lattice distortions. The temperature dependence of the Sr_2MnIrO_6 electric resistivity indicates that Sr_2MnIrO_6 is a narrow band-gap insulator.

[1] W. Witczak-Krempa *et al.*, Annu. Rev. Condens. Matter Phys. **5**, 57 (2014).

MA 60.7 Fri 11:00 HSZ 101

Thermal expansion and magnetostriction of single-crystalline $LiFePO_4$ — •Sven Krippendorf, Christoph Neef, Anna Pollithy, Norbert König, and Rüdiger Klingeler — Kirchhoff Institute of Physics, Heidelberg University, Germany

We report thermal expansion and magnetostriction studies in magnetic fields up to 17 T on $LiFePO_4$ single crystals grown by the optical floating zone method. The onset of long range antiferromagnetic order at $T_N = 50.1(5)$ K is associated with pronounced λ-like anomalies of the thermal expansion coefficient α. In addition, there is an extended regime of fluctuations up to ≥ 80 K. We observe an additional anomaly in the linear thermal expansion coefficient of the crystalline *b*- and *c*-axis well below T_N which field dependence is studied in detail. Grüneisen analysis reveals it as a new phenomenon which is not of purely magnetic origin and that has not been reported in the literature so far.

MA 60.8 Fri 11:15 HSZ 101

Universal distribution of magnetic anisotropy of impurities in ordered and disordered nanograins — •Attila Szilva[1], Peter Balla[2,3], Olle Eriksson[1], Gergely Zarand[4], and Laszlo Szunyogh[2,5] — [1]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budafoki ut 8, H-1111 Budapest, Hungary — [3]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, P.O. Box 49, H-1525 Budapest, Hungary — [4]BME-MTA Exotic Quantum Phases *Lendulet* Group, Institute of Physics, Budapest University of Technology and Economics, H-1521 Budapest, Hungary — [5]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budafoki u *t 8, H-1111 Budapest, Hungary

We examine the distribution of the magnetic anisotropy experienced by a magnetic impurity embedded in a metallic nanograin. Confinement of the electrons induces a magnetic anisotropy that is large, and can be characterized by five real parameters, coupling to the quadrupolar moments of the spin. For disordered grains they are randomly distributed and, for stronger disorder, their distribution is found to be characterized by random matrix theory. The probability of having small magnetic anisotropies is suppressed below a characteristic scale, leading to anomalies in the specific heat and the susceptibility at temperatures and produces distinct structures in the magnetic excitation spectrum of the clusters that should be possible to detect experimentally.

MA 60.9 Fri 11:30 HSZ 101

The influence of the anti-phase domain structure on the magnetic properties in $Ni_2MnAl_{0.5}Ga_{0.5}$ — •Pascal Neibecker[1,2], Xiao Xu[2], Winfried Petry[1], Ryosuke Kainuma[2], and Michael Leitner[1] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching, Germany — [2]Department of Materials Science, Tohoku University, Sendai 980-8579, Japan

The characteristic length scale of the $L2_1$ anti-phase domain (APD) structure has been observed to have a significant influence on the magnetic properties of Heusler alloys [1]. The ideal system to study this phenomenon is $Ni_2MnAl_{0.5}Ga_{0.5}$ where the phase transition temperatures and diffusion kinetics allow to adjust a variety of combinations of degrees of $L2_1$ order and APD sizes. Here, we investigate the effect of the APD length scale on the magnetic properties in $Ni_2MnAl_{0.5}Ga_{0.5}$ via probing the entire accessible parameter space of APD sizes and degrees of $L2_1$ order, starting from B2 order and adjusting different APD scale/ atomic order values via appropriate annealing procedures. We show that both contributions, APD size and degree of order, can clearly be distinguished in magnetization measurements and we use those measurements to follow their respective temporal evolution. In a second step, we simulate APD structures and degrees of $L2_1$ order using Monte Carlo simulations and show via magnetic simulations on the pre-set APD structures that we can reproduce all characteristic features of the experimentally observed magnetization curves.

[1] H. Ishikawa, et al., Acta Materialia 56 (2008), p. 4789-4797

MA 60.10 Fri 11:45 HSZ 101

Spin disorder resistivity of iron at the Earth's core conditions — •Vaclav Drchal[1], Josef Kudrnovsky[1], Ilja Turek[2], David Wagenknecht[2], and Sergii Khmelevskyi[3] — [1]Institute of Physics, Acad. Sci. Czech Rep., Praha, Czech Republic — [2]Department of Condensed Matter Physics, Charles University, Praha, Czech Republic — [3]Center for Computational Materials Science, Vienna University of Technology, Vienna, Austria

Using ab initio calculations and linear response theory, we study the spin-disorder resistivity (SDR) at the Earth's core conditions. The SDR is caused by the scattering of electrons on fluctuating local moments that are stabilized at high temperatures by the magnetic entropy. As an illustration we consider bcc iron. We find a relatively large SDR of order 25 $\mu\Omega$cm but its contribution to the total resisistivity including also phonons is strongly suppressed at high temperatures, leading thus to a large violation of the Matthiessen rule. We also briefly discuss the effects of non-magnetic impurities.

MA 61: Skyrmion Dynamics

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

MA 61.1 Fri 9:30 HSZ 401

Quantifying the Dzyaloshinskiǐ Moriya Interaction using traveling waves with stationary envelopes — •Benjamin Zingsem[1], R. E. Camley[2], R. Salikhov[1], R. Meckenstock[1], D. Spoddig[1], R. L. Stamps[3], and M Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, 47057 Duisburg, Germany — [2]Center for Magnetism and Magnetic Nanostructures, University of Colorado at Colorado Springs, Colorado Springs, Colorado 80918, USA — [3]SUPA, School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, UK

In the presence of Dzyaloshinskii Moriya Interaction (DMI) the magnon dispersion becomes nonreciprocal [1], meaning that counter-propagating waves of the same frequency have different wavevectors. In this combined experimental and theoretical study, we show that this property implies that spinwave eigenmodes of confined systems, such as nanodots, exibit unusual dynamics i.a. they posess aspects of propagating and standing waves. This new type of *standing wave* results in eigenmodes, emerging at microwave excitations (e.g. ferromagnetic resonance (FMR)), which would be undetectable wihtout DMI. Thus the presence of DMI imposes a unique fingerprint on FMR spectra of confined systems which allows for unambigous quantification of the DMI. [2]

[1] J-H Moon, et al. Phys. Rev. B, 88:184404, Nov 2013. [2] Benjamin W. Zingsem, Michael Farle, Robert L. Stamps, and Robert E. Camley. The unusual nature of confined modes in a chiral system. arXiv:1609.03417, 2016.

MA 61.2 Fri 9:45 HSZ 401

Isolated skyrmion dynamics in confined helimagnetic nanostructures — •Marijan Beg[1], David I. Cortés-Ortuño[1], Weiwei Wang[1,2], Rebecca Carey[1], Mark Vousden[1], Ondrej Hovorka[1], and Hans Fangohr[1] — [1]Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, United Kingdom — [2]Department of Physics, Ningbo University, Ningbo, 315211, China

Understanding the dynamic response of skyrmionic states is of importance both from the aspect of fundamental physics as well as for their manipulation. We explore the isolated skyrmion ground state dynamics in a 150 nm diameter FeGe disk sample at zero external magnetic field using a full three-dimensional model, which includes the demagnetisation energy and does not make any assumptions about the translational invariance of magnetisation in the out-of-film direction. We compute all existing eigenmodes employing the eigenvalue method, and then, using the ringdown method we determine which eigenmodes can be excited using two different experimentally feasible excitations (in-plane and out-of-plane). Finally, we investigate how the resonant frequencies change when the external magnetic bias field and the disk sample diameter are varied. We observe the existence of only one gyrotropic and one breathing low-frequency eigenmode, and the field-dependent power spectral density maps suggest that the gyrotropic eigenmode is the reversal mode of an isolated skyrmion state. This work was supported by the EPSRC's EP/G03690X/1 and EP/N032128/1 grants and the Horizon 2020 European Research Infrastructure project (676541).

MA 61.3 Fri 10:00 HSZ 401

Motion of higher-order skyrmions driven by spin-orbit torques — •Ulrike Ritzmann[1], Stephan von Malottki[2], Joo-Von Kim[3], Karin Everschor-Sitte[1], Jairo Sinova[1], Stefan Heinze[2], and Bertrand Dupé[1] — [1]Johannes Gutenberg Universität Mainz, Mainz, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [3]Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, Orsay, France

Skyrmions are topologically stabilized spin structures on the nanometer scale. They can be manipulated with electric current densities that are orders of magnitude lower than those required for moving domain walls. Especially, isolated magnetic skyrmions can also occur in ultrathin transition metal films at surfaces [1,2] and interfaces [3].

We have shown previously that skyrmions exist in these systems due to a competition between magnetic interactions beyond the first nearest neighbour approximation. We have found that this competition can stabilize higher order skyrmions in Pd(fcc)/Fe/Ir(111) such as antiskyrmions (S=-1) and higher order antiskyrmions (S=-2) [4].

Here, we present a study on the motion of these skyrmions via spin transfer torques. The displacement of skyrmions can be described in a rigid-body approximation [5], whereas the motions of antiskyrmions require to take internal degrees of freedom into account.

[1] Romming et al., Science 341, 636 (2013); [2] B. Dupé et al., Nat. Commun. 5, 4030 (2014); [3] B. Dupé et al., Nat. Commun. 7, 11779 (2016); [4] B. Dupé et al., New J.Phys. 18, 055015 (2016); [5] Thiele, Phys. Rev. Lett. 30, 230 (1973)

MA 61.4 Fri 10:15 HSZ 401

Towards ferromagnetic resonance in scanning tunnelling microscopy using homodyne detection — •Marie Hervé, Moritz Peter, Timofey Balashov, and Wulf Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We report on the experimental development of a technique combining ferromagnetic resonance (FMR) and spin-polarized STM. The concept of this technique, inspired by the spin torque diode effect [1], is based on the homodyne detection of the resonance signal. A continuous radio-frequency (rf) voltage is mixed to the bias voltage of the STM. If there is a magnetization precession under the STM tip, the tunneling conductance will be modulated at the resonance frequency. When the rf signal mixed to the tunneling junction hits the resonance frequency of the precession, the tunneling current is rectified. This rectified current can be detected by a conventional transimpedance amplifier. To test this method we investigated the skyrmionic spin structure Fe(0.4ML)/Ir(111) [2]. The experiments allowed to reveal a resonant signal at 615 MHz. This signal is interpreted as a FMR feature.

[2] A. A. Tulapurkar, Y. Suzuki, A. Fukushima, H. Kubota, H. Maehara, K. Tsunekawa, D. D. Djayaprawira, N. Watanabe and S. Yuasa, Nature 438, 339 (2005) [4] S. Heinze, K. von Bergmann, M. Menzel, J. Brede, A. Kubetzka, R. Wiesendanger, G. Bihlmayer and S. Blügel, Nature Physic 7, 713 (2011)

MA 61.5 Fri 10:30 HSZ 401

Short Wavelength Magnons in Magnetic Vortex Structures — Georg Dieterle[1], •Johannes Förster[1], Ajay Gangwar[2], Markus Weigand[1], and Sebastian Wintz[3,4] — [1]Max-Planck-Institut für Intelligente Systeme, Stuttgart — [2]Universität Regensburg — [3]Paul Scherrer Institut, Villigen, Schweiz — [4]Helmholtz Zentrum Dresden-Rossendorf

In recent years magnonics has become one of the prime topics in magnetics research. The prospect of possible technological applications has played a major part in this development. The reliable generation of spin waves with short wavelengths is an ongoing challenge in this field, as it is difficult by means of a patterned stripline antenna. Here we report on the imaging of spiral shaped short wavelength spin waves emitted by a magnetic vortex core in a permalloy disc. We take advantage of the magnetic perturbation generated by the small moving core, 10-20nm in diameter, to generate spin waves of sub-100nm wavelength. Imaging of these waves has been done using Time-Resolved Scanning Transmission X-Ray Microscopy at the MAXYMUS endstation of the BESSY II synchrotron facility [1]. The experimentally derived dispersion relations match with analytical expressions for hybridized modes between Damon-Eshbach and exchange dominated magnons in infinite ferromagnetic films. This holds as well for our micromagnetic simulations in these vortex structures.

[1] M. Noske et al., J. Appl. Phys. 119, 173901 (2016)

MA 61.6 Fri 10:45 HSZ 401

Skyrmion production on demand by homogeneous DC currents — •Karin Everschor-Sitte[1], Matthias Sitte[1], Thierry Valet[1], Jairo Sinova[1,2], and Artem Abanov[3] — [1]JGU Mainz, Germany — [2]Academy of Sciences of the Czech republic, Czech Republic — [3]Texas A&M University, USA

Topological magnetic textures – skyrmions – have become a major player in the design of next-generation magnetic storage technology due to their stability and the control of their motion by ultra-low current densities. A major challenge to achieve this new skyrmion-based technology is the controlled and systematic creation of magnetic skyrmions without the need of complex setups. We demonstrate a solution to this challenge by showing how to create skyrmions and other magnetic textures in ferromagnetic thin films by means of a homogeneous DC current and without requiring any standard "twisting" interactions like Dzyaloshinskii-Moriya. This is possible by exploiting a dynamical instability arising by the interplay of current-induced spin-transfer torque and locally engineered anisotropies. The magnetic textures are created controllably, efficiently, and periodically with a period that can be tuned by the applied current strength. We propose specific experimental setups realizable with simple materials, such as cobalt or permalloy, to observe the periodic formation of skyrmions. Thus our findings allows for the production of skyrmions on demand in simple ferromagnets by homogeneous DC currents.

MA 61.7 Fri 11:00 HSZ 401

Single magnetic skyrmions and skyrmion clusters in the helical phase — •Jan Müller[1], Rajeswari Jayaraman[2], Fabrizio Carbone[2], and Achim Rosch[1] — [1]Institut für Theoretische Physik, Universität zu Köln, D-50937 Köln, Germany — [2]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Magnetic skyrmions are tiny magnetic whirls which can be stabilized by spin-orbit interactions in magnets lacking inversion symmetry. They are small, extremely stable and can be manipulated by tiny forces. The properties of skyrmions embedded in a ferromagnetic environment have been intensively studied. I will show that within our numerical simulations single skyrmions and clusters of skyrmions can also form in a helical phase and investigate theoretically the energetics and dynamics of such skyrmions. The helical background provides natural one-dimensional channels along which a skyrmion can move rapidly. In contrast to skyrmions in ferromagnets, the skymion-skyrmion interaction has a strong attractive component and thus skyrmions tend to form clusters with characteristic shapes. These clusters are directly observed in transmission electron microscopy measurements in films of the insulating skyrmion material Cu_2OSeO_3. Topological quantization, high mobility and the confinement in channels may be useful for future spintronics devices.

MA 61.8 Fri 11:15 HSZ 401

Magnetic Skyrmions on a Two-Lane Racetrack — •Jan Müller — Institut für Theoretische Physik, Universität zu Köln, D-50937 Köln, Germany

Magnetic skyrmions are particle-like textures in the magnetization, characterized by a topological winding number. Nanometer-scale skyrmions have been observed at room temperature in magnetic multilayer structures. The combination of small size, topological quantization, and their efficient electric manipulation makes them interesting candidates for information carriers in high-performance memory devices. A skyrmion racetrack memory has been suggested where information is encoded in the distance between skyrmions moving in a one-dimensional nanostrip. Here, I propose an alternative design where skyrmions move in two (or more) parallel lanes and the information is stored in the lane number of each skyrmion. Such a multilane track can be constructed by controlling the height profile of the nanostrip. Repulsive skyrmion-skyrmion interactions in narrow nanostrips guarantee that skyrmions on different lanes cannot pass each other. Current pulses can be used to induce a lane change. Combining these elements provides a robust, efficient design of skyrmion-based storage devices.

MA 62: Magnetic Imaging (Experimental Techniques)

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

MA 62.1 Fri 9:30 HSZ 403

Development of a X-ray zone plate microscope for magnetic domain imaging in the EUV range — •Andreas Schümmer[1], Markus Gilbert[1], Christine Jansing[1], Hans-Christoph Mertins[1], Roman Adam[2], Claus Schneider[2], Larissa Juschkin[3], Carsten Westphal[4], Ulf Berges[4], and Sven Stempfhuber[4] — [1]University of Applied Sciences, FH Münster, 48565 Steinfurt, Germany — [2]Forschungszentrum Jülich, Peter Grünberg Institut (PGI-6), 52428 Jülich, Germany — [3]Rheinisch-Westfälische Technische Hochschule Aachen, 52062 Aachen, Germany — [4]TU Dortmund, Zentrum für Synchrotronstrahlung, 44227 Dortmund, Germany

We present the current development of a Scanning Reflection X-ray Microscope (SRXM) based on zone plate focusing in the extreme ultraviolet (EUV) spectral range at the DELTA beamline 12. The SRXM is dedicated to magnetic domain imaging in magnetic films, surface of thick samples and buried layers exploiting magneto-optical reflection spectroscopy employing T-MOKE, L-MOKE, XMLD and XMCD [1]. We present the construction of the microscope and discuss the fabrication of zone plates using absorbing gold structures as well as phase shifting PMMA structures. Both variants are designed for EUV applications across the Fe 3p to Ni 3p edges and are deposited on Si3N4 membranes. Ray tracing calculations for the beamline including zone plate optics are presented as well. [1] M. Tesch, M. Gilbert, H - Ch. Mertins, D. Bürgler et al., Appl. Opt. 52, 4294 (2013)

MA 62.2 Fri 9:45 HSZ 403

Time-resolved X-ray detected ferromagnetic resonance with spatial resolution using scanning X-ray microscopy — •Taddäus Schaffers[1], Andreas Ney[1], Verena Ney[1], Katharina Ollefs[2], Ralf Meckenstock[2], Detlef Spoddig[2], Hendrik Ohldag[3], and Michael Farle[1] — [1]Division of Solid State Physics, Johannes Kepler University, Altenberger Str. 69, 4040 Linz, AUSTRIA — [2]Experimental Physics, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, GERMANY — [3]Stanford Synchrotron Radiation Laboratory, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA

Recently we have combined a scanning transmission x-ray microscopy (STXM) setup with a novel microwave synchronization scheme for studying high frequency magnetization dynamics in the GHz regime [1] enabeling spatially resolved ferromagnetic resonance studies on magnetic micro- and nanostructures. Compared to other spatially resolved ferromagnetic resonance (FMR) detection schemes [2] the STXM-FMR setup features element-selectivity as well as a high temporal and spatial resolution down to 18 ps and 35 nm [1]. We will briefly present the STXM-FMR detection [1]. In addition, first results derived for coupled magnetic structures will be discussed. We are able to directly image the magnetic excitations and identify the contributions of the respective constituents to conventional FMR spectra.

References [1] S. Bonetti et al., Rev. Sci. Instrum. 86, 093703 (2015) [2] R. Meckenstock, Rev. Sci. Instrum. 79, 041101(2008)

MA 62.3 Fri 10:00 HSZ 403

Investigating magnetism in nano-sized goethite particles — •David M. Bracher[1,2], Tatiana M. Savchenko[1], Marcus Wyss[2], Giorgia Olivieri[3], Matthew A. Brown[3], Frithjof Nolting[1], Martino Poggio[2], and Armin Kleibert[1] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland — [2]Department of Physics and Astronomy, University of Basel, CH-4056 Basel, Klingelberstrasse 82, Switzerland — [3]Laboratory for Surface Science and Technology, Department of Materials ETH Zürich, CH-8093,HCI G543

Goethite (α-FeOOH) is abundant in the earth crust and, thus, an important marker for paleomagnetism and paleoclimatology. Bulk goethite exhibits antiferromagnetic order at room temperature. However, nano-sized goethite often has of a complex polycrystalline morphology and possibly altered magnetic properties. Combining X-ray photo-emission electron microscopy with scanning electron microscopy we correlate the magnetism and morphology of individual goethite nanoparticles. Synthetic goethite nanoparticles are dispersed on silicon substrates with gold markers facilitating particle identification. X-ray magnetic linear dichroism is capable of probing antiferromagnetism, while X-ray magnetic circular dichroism tracks eventual uncompensated magnetic moments, which may emerge from structure and size of the particles. Angular- and temperature-dependent investigations suggest antiferromagnetism in the particles below the bulk Néel temperature and anisotropic properties at room temperature without indication of uncompensated moments. These results will be discussed with respect to the morphology of the particles.

MA 62.4 Fri 10:15 HSZ 403

Measuring broadband magnetic fields on the nanoscale using a hybrid quantum register — •Ingmar Jakobi[1], Sven Bodenstedt[1], Fadi El Hallak[2], Muhammad Asif Bashir[2], Ya Wang[1], Durga B. R. Dasari[1], Philipp Neuamnn[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Seagate Technology

Modern hard disk recording heads are the product of decades of development and a marvel of engineering. A microscopic electromagnet is able to flip the magnetization of a 20 nm wide bit on the recording medium while it flies by at 10000 rpm. This implies that the produced magnetic fields are strong (B ~ 1T), fast (GHz bandwidth) and especially local. Gradients of up to 10 mT/nm are among the strongest that mankind can produce. However these devices have been miniaturized beyond the capabilities of conventional sensors which impairs further development.

Here we present a suitable magnetometer that can resolve the magnetic field of recording heads on the nanoscale. Single nitrogen-vacancy (NV) defect centers in diamond can measure a broad range of field strengths and frequencies. As their spin is mostly confined to a single lattice site the detection volume is on the atomic scale and the spatial resolution only depends on the positioning of the host diamond. In return the unique features of recording heads are of particular interest for spin research ranging from nanoscale magnetic resonance imaging to quantum information processing.

[1] I. Jakobi et al., Nature Nanotechnology, 2016

15 min. break.

MA 62.5 Fri 10:45 HSZ 403

Resolution enhancement of magneto-optical images using modern image processing algorithms — •Dmitry Berkov[1], Natalia Gorn[1], Ivan Soldatov[2], and Rudolf Schäfer[2] — [1]General Numerics Research Lab, Moritz-von-Rohr-Str. 1A, Jena, Germany — [2]IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

A systematic study of the possibilities to suppress the noise and enhance the resolution of magneto-optical images using modern image processing methods is presented. We compare the performance of various methodical classes of processing algorithms, including regularized pseudoinverse filter, Wiener filter, Richardson-Lucy-algorithm [1,2] and fast Total Variation regularization [3,4]. In addition, we discuss experimental possibilities to obtain the point spread function of a Kerr microscope, which knowledge is still crucial for the effective resolution enhancement of this instrument, despite the existence of socalled blind deconvolution methods. Numerical test results and results obtained on magnetic films with skyrmion-like structures are shown

1. L.B. Lucy, An iterative method for the rectification of observed distributions, Astronomical J. 79 (1974) 745 2. W.H. Richardson, Bayesian-based iterative method of image restoration, J. Opt. Soc. Am. 62 (1972) 55 3. L. Rudin, S. Osher, Total variation based image restoration with free local constraints, Proc. 1st IEEE ICIP, 1 (1994) 31 4. C.R. Vogel, M. E. Oman, Iterative methods for total variation denoising, SIAM J. Sci. Comput. 17 (1996) 227 5. J.N. Caron, N.M. Namazi, C.J. Rollins, Noniterative blind data restoration by use of an extracted filter function, Appl. Opt. 41 (2002) 6884

MA 62.6 Fri 11:00 HSZ 403

Soft magnetic sensors for the visualization of supercurrents — •Claudia Stahl[1], Stephen Ruoss[1], Julian Simmendinger[1], Joachim Gräfe[1], Markus Weigand[1], Gisela Schütz[1], and Joachim Albrecht[2] — [1]Max Planck Institute for Intelligent Systems, Heisenbergstr. 3, 70569 Stuttgart, Germany — [2]Research Institute for Innovative Surfaces, FINO, Aalen University, Beethovenstr. 1, 73430 Aalen, Germany

In this work soft ferromagnetic thin $Co_{40}Fe_{40}B_{20}$ films are utilized as sensor layers on top of the superconductor $YBa_2Cu_3O_{7-\delta}$ in order to map the current density distribution. For highest spatial and magnetic resolution we use scanning x-ray microscopy based on the XMCD (x-ray magnetic circular dichroism) effect [1]. We show the correlation between the topography of the sample and the pinning scenario of magnetic flux in the superconductor using the high spatial resolution of x-ray microscopy and the magnetic contrast of the sensor layer [2]. The x-ray measurements are carried out at our scanning x-ray microscope MAXYMUS at Bessy II, HZB Berlin with the new low temperature setup.

As quick and easy accessible alternative and supplement, low temperature laser-MOKE (magneto-optical Kerr-effect) and FORC (first order reversal curve) [3] analysis of the superconductor/ferromagnet bilayers are conducted. These measurements are used to analyze the eligibility of different sensor materials as well as to complement the x-ray images. [1] APL 106, 022601 (2015). [2] New J. Phys. 18, 103044 (2016). [3] Rev. Scient. Instrum. 85, 023901 (2014).

MA 62.7 Fri 11:15 HSZ 403

Deconvolution of distinct magnetooptical response of Ru/permalloy/Ta thin film stacks in recognition of different underlying substrates — •Rajkumar Patra[1], Danilo Bürger[1], Roland Mattheis[2], Hartmut Stöcker[3], Manuel Monecke[4], Georgeta Salvan[4], Stefan Pofahl[5], Rudolf Schäfer[5], Oliver G. Schmidt[1,6], and Heidemarie Schmidt[1] — [1]Material Systems for Nanoelectronics, TU Chemnitz, 09107, Germany — [2]Leibniz Institute for Photonic Technology IPHT, Jena, Germany — [3]Institute of Experimental Physics, TU Bergakademie Freiberg, 09596, Germany — [4]Semiconductor Physics, TU Chemnitz, 09107, Germany — [5]Institute for Metallic Materials, IFW Dresden, 01069, Germany — [6]Institute for Integrative Nanosciences, IFW Dresden, 01069, Germany

The magnetooptical (MO) response of permalloy (Py) films on a SiO2/Si and a ZnO substrate was studied using VMOGE [1] in a wavelength range from 300 nm to 1000 nm. Textured growth of the Py films was confirmed by GAXRD. Thickness independent MO conductivity matrix of Py films in the Ru/Py/Ta thin film stacks was modeled [2] and found to be independent of the underlying substrate. Features in the modeled off-diagonal elements of MO conductivity matrix of Py are related with electronic interband transitions between the d-bands from individual Ni and Fe. Magnetic domains have been observed by Kerr microscopy up to a 10 mT out-of- plane magnetic field and are related with corresponding out-of- plane SQUID-VSM magnetometry.

[1] K. Mok et al. Rev. Sci. Instr. 82 (2011) 033112. [2] K. Mok et al. J. Appl. Phys. 110 (2011) 123110; Phys. Rev. B 84 (2011) 094413.

MA 62.8 Fri 11:30 HSZ 403

Giant enhancement of magneto-optical anisotropy in Co-films by ultrathin nonmagnetic overcoats — •Patricia Riego, Lorenzo Fallarino, Jon Ander Arregi, and Andreas Berger — CIC nanoGUNE, San Sebastian (Spain)

We explore the effect of ultrathin nonmagnetic (Pt) overcoat layers onto the magneto-optical (MO) properties of hcp Co by means of generalized magneto-optical ellipsometry (GME). It has been previously shown that hcp Co displays MO anisotropy, i.e., distinct MO coupling factors when the magnetization is aligned with different crystallographic axes of the material. In this work, we show that an ultrathin Pt overcoat enhances this MO anisotropy of Co up to 400%, as well as its Kerr rotation up to 250%, and that these effects depend very strongly on the exact overcoat thickness. The effect saturates when the Pt overcoat is 1.5 nm thick, indicating that the observed effect is interfacial in nature. Our modelling work demonstrates that such enhancements can be consistently explained by a strong and anisotropic modification of the MO response in the Co/Pt interface region.

MA 63: Topological Insulators III (joined session with TT)

Time: Friday 9:30–12:30 Location: POT 251

MA 63.1 Fri 9:30 POT 251

Time-dependent defects in photonic topological insulators — •Christina Jörg[1], Fabian Letscher[1,2], Michael Fleischhauer[1], and Georg von Freymann[1,3] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Fraunhofer-Institute for Physical Measurement Techniques (IPM), Kaiserslautern, Germany

To model topological insulators by means of classical optics, we fabricate arrays of evanescently coupled waveguides. These waveguides are about 1 μm in diameter at an aspect ratio of 1:500, and helically curved. The inverse of the waveguide array is fabricated via direct laser writing in a negative-tone photoresist. Subsequently the sample is infiltrated with a material of higher refractive index, creating low-loss 3D waveguides. Arranging the waveguides on a honeycomb-lattice, a robust edge mode exists due to topological protection [1]. This means that light moves along the edge unidirectionally, and even walks around defects without backscattering. Here, we discuss defects with time-dependent coupling, i.e., one waveguide with a different helicity than the rest of the waveguides. We examine three kinds of time-dependent defects: a) a straight waveguide, b) a waveguide with opposite helicity, c) a waveguide with same helicity but shifted by half a helix pitch in the z-direction. In all three cases the edge mode moves along the edge regardless of the defect, going partially around the defect and partially through it.

[1] M. C. Rechtsman et al., Nature 496, 196-200 (2013).

MA 63.2 Fri 9:45 POT 251

Aharonov-Bohm-type oscillations in HgTe topological insulator nanowires — •Johannes Ziegler[1], Raphael Kozlovsky[2], Ming-Hao Liu[2], Dmitriy Kozlov[1,3,4], Hubert Maier[1], Ze Don Kvon[3,4], Nikolay Mikhailov[3], Sergey Dvoretsky[3], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, Germany — [3]A.V. Rzhanov Institue of Semiconductor Physics, Novosibirsk, Russia — [4]Novosibirsk State University, Russia

In topological insulator nanowires, the helical surface states form a conducting cylinder enclosing the bulk. These states give rise to Aharonov-Bohm-type oscillations when a magnetic field is applied along the wire axis [1]. These oscillations, periodic with the flux quantum Φ_0, are predicted to change their phase periodically as a function of the Fermi level E_f. We fabricate nanowires with typical cross sections of 80 x 150 nm using an optimized wet etching process to maintain the high mobility and mean free path. In our experiments, we found, as expected, h/e periodic oscillations as a function of magnetic flux Φ with alternating maxima and minima as a function of E_f for $\Phi/\Phi_0 = 1/2$ and $\Phi/\Phi_0 = 1$. We compare the resulting periodicity with a simple model and electrostatic simulations.

[1] J.H. Bardarson *et al.*, Phys. Rev. L **105**, 156803 (2010)

MA 63.3 Fri 10:00 POT 251

Correlation and current anomalies in helical quantum dots — •Christophe De Beule[1], Niccolò Traverso Ziani[2], Mohammad Zarenia[1], Bart Partoens[1], and Björn Trauzettel[2] — [1]Department of Physics, University of Antwerp, 2020 Antwerp, Belgium — [2]Institute of Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany

We investigate the ground-state properties of a quantum dot on the surface of a time-reversal invariant topological insulator. Confinement is realized by ferromagnetic barriers and Coulomb interaction is treated with exact diagonalization. The topological origin of the dot has several consequences: (i) spin polarization increases and the ground state exhibits quantum phase transitions as a function of interaction strength, (ii) the onset of Wigner correlations takes place mainly in one spin channel, and (iii) the ground state is characterized by a persistent current that changes direction as a function of the radius.

We also consider the effect of superconducting correlations on the properties of the quantum dot. This allows us to analyze the influence of perturbations that violate particle-number conservation on the formation of the Wigner molecule.

MA 63.4 Fri 10:15 POT 251

Double topological surface states in strained alpha-Sn — •Victor Rogalev[1], Tomáš Rauch[2], Markus Scholz[1], Felix Reis[1], Lenart Dudy[1], Andrzej Fleszar[3], Marius-Adrian Husanu[4], Vladimir Strocov[4], Jürgen Henk[2], Ingrid Mertig[2,5], Jörg Schäfer[1], and Ralph Claessen[1] — [1]Physikalisches Institut und Röntgen Center for Complex Materials Systems, Universität Würzburg, 97074 Würzburg, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany — [3]Institut für Theoretische Physik und Astronomie, Universität Würzburg, 97074 Würzburg, Germany — [4]Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen, Switzerland — [5]Max Planck Institute for Microstructure Physics, 06120 Halle (Saale), Germany

The low temperature phase of Sn, α-Sn, is a semimetal with two pairs of "inverted" bands and zero energy band gap, which can be increased by strain. Experimental works revealed so far only one topological surface state (TSS) that bridges one pair of inverted bands.

By means of a combined experimental and theoretical approach we show that the electronic structure of the compressively strained α-Sn (001) thin film hosts an additional TSS in the valence band due to the second band inversion. This sub-surface localized TSS is directly accessed by soft X-ray angle-resolved photoemission with high probing depth. The second TSS reveals a much stronger hybridization with bulk states, in contrast to the already known surface-localized TSS. We show that such difference is consistent with the analysis of orbital composition of bulk and surface states.

MA 63.5 Fri 10:30 POT 251

Stencil lithography of MBE grown superconductors on top of topological insulator thin films — •Michael Schleenvoigt, Peter Schüffelgen, Daniel Rosenbach, Tobias W. Schmitt, Martin Lanius, Benjamin Bennemann, Stefan Trellenkamp, Elmar Neumann, Gregor Mussler, Thomas Schäpers, and Detlev Grützmacher — Peter Grünberg Institute 9, Forschungszentrum Jülich & JARA-FIT, 52425 Jülich, Germany

A stack of the two binary 3D topological insulators Bi2Te3 (n-type doped) and Sb2Te3 (p-type) forms a PN-heterostructure. Growing those topological heterostructures by means of MBE offers the possibility to tune the Fermi level of the upper surface to the Dirac-point. To protect the delicate Dirac system from degradation and oxidation we cap our heterostructures with a thin Al layer, before taking the sample to ambient conditions. We further developed this process to allow for in-situ growth of two different Al layers, i.e. a thin 1-2 nm Al layer on the full wafer followed by a thick Al film on well-defined areas by means of stencil lithography. The thin Al layer will subsequently oxidize after exposure to air and protect the delicate topological surface, whereas the thick Al layer with spatial extent in the (sub-)micrometer range will serve as superconducting contacts. Superconductor-Topological Insulator-Superconductor junctions with lateral dimensions in the nm range have then been fabricated. Despite the in-situ deposition, transport measurements and transmission electron microscope analysis indicate a low transparency, due to an intermixed region at the interface between topological insulator thin film and metallic Al.

Coffee Break

MA 63.6 Fri 11:15 POT 251

Induced superconductivity in lateral topological Josephson junctions with $(Sb_{0.94}Bi_{0.06})_2Te_3$ interlayer — •Daniel Rosenbach[1], Peter Schüffelgen[1], Martin Lanius[1], Gregor Mussler[1], Stefan Trellenkamp[1], Martin P. Stehno[2], Alexander Brinkman[2], Detlev Grützmacher[1], and Thomas Schäpers[1] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]MESA+ Institute for Nanotechnology, University of Twente, 7500 AE Enschede, The Netherlands

The long sought Majorana fermion is predicted to arise in superconducting systems with p-wave pair correlation symmetry. Induced superconductivity in topological insulator thin films is expected to show partly p-wave pairing, such that Majorana zero modes (MZM) are thought to exist at the interface with a conventional s-wave superconductor. A current carried by these zero modes is supposed to show a doubled periodicity in the current-phase relation, compared to con-

ventional modes.
Molecular beam grown topological insulator ternary alloy thin films, of given composition, with a thin aluminum-oxide capping layer, have been prepared with lateral niobium superconducting contacts. Junctions of various geometries have been measured at low temperatures. The response to an externally applied magnetic field and to a radio-frequency signal is strongly dependent on the current-phase relation of the conductive modes. Characterization therefore includes an analysis of various Fraunhofer diffraction pattern as well as Shapiro step measurements at different frequencies.

MA 63.7 Fri 11:30 POT 251

Nontrivial topological phases in quantum mechanical many-body systems with gain and loss effects — •Marcel Klett, Holger Cartarius, and Guenter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Non-Hermitian $\mathcal{PT}$-symmetric potentials are capable of effectively describing quantum systems with balanced in- and outfluxes. They allow for the existence of a $\mathcal{PT}$-symmetric phase with purely real energy spectra of the non-Hermitian Hamiltonian. Recently a possible relation between the appearance of the $\mathcal{PT}$-symmetric phase and topologically nontrivial states were found in two studies of simple model systems. However, they came to opposite conclusions. In the Su-Schrieffer-Heeger (SSH) model [1] the topological phase has a major influence. As soon as topologically nontrivial states appear $\mathcal{PT}$ symmetry gets broken. This is in contrast to the non-Hermitian Kitaev model [2], in which $\mathcal{PT}$ symmetry breaking does not depend on the topological phase. Our work is based on including different non-Hermitian potentials in the SSH model as well as the Kitaev model. We perform exact calculations of the eigenvalues and the eigenstates, clarify the relation between $\mathcal{PT}$ symmetry and topological phases, and explain why opposite results were found in the above mentioned systems.
[1] Baogang Zhu et al., Phys. Rev. A **89**, 062102 (2014)*
[2] Xiaohui Wang et al., Phys. Rev. A **92**, 012116 (2015)

MA 63.8 Fri 11:45 POT 251

Probing topological edge states in HgTe-based quantum wells by terahertz photogalvanic spectroscopy — •Kathrin-Maria Dantscher[1], Dimitry A. Kozlov[2], Maria-Theresia Scherr[1], Sebastian Gebert[1], Jan Bärenfänger[1], Mikhail Durnev[3], Sergey A. Tarasenko[3], Vasily V. Bel'kov[3], Nikolay N. Mikhailov[2], Sergey A. Dovertsky[2], Ze Dong Kvon[2], Dieter Weiss[1], and Sergey D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.V. Rzhanov Institute of Semiconductor Physics, Novosibirsk 630090, Russia — [3]Ioffe Institute, St.Petersburg, Russia

We report on the observation of a chiral photogalvanic current excited by terahertz laser radiation in the edge channels of HgTe-based 2D topological insulators (TI). The direction of the edge photocurrent reverses by switching the radiation polarization from the right- to left-handed one and, for fixed helicity, has opposite direction for opposite edges. The chiral edge photocurrent is detected in a wide range of gate voltages and reverse the sign twice upon variation of the gate voltage. We show that the data reveal that in the TI-regime the photocurrent is caused by photoionization of helical edge electrons to the conduction band, discuss the microscopic model of this phenomena and present the developed microscopic theory.

MA 63.9 Fri 12:00 POT 251

Topological phase space study of a generalized Kane-Mele spin-orbit Hamiltonian — •Tobias Frank, Petra Högl, Martin Gmitra, Denis Kochan, and Jaroslav Fabian — Theoretische Physik, Universität Regensburg

We study a generalized Kane-Mele [1] graphene spin-orbit coupling Hamiltonian, that is able to describe hybrid systems like graphene on transition metal dichalcogenides [2] or graphene - metal interfaces [3] with broken inversion symmetry. We identify the topological phase space in terms of its Z_2 invariant by variation of spin-orbit coupling parameters. We as well analyze the bulk-edge correspondence in terms of zigzag and armchair ribbons. We find that spin-orbit coupling proximitized graphene can exhibit helical edge states at the zigzag boundary even if it is in the trivial topological phase.

This work is supported by the DFG GRK 1570, SFB 689, and European Union Seventh Framework Programme under Grant Agreement No. 604391 Graphene Flagship.

[1] C. L. Kane and E. J. Mele, PRL 95 226801 (2005)
[2] M. Gmitra, D. Kochan, P. Högl, and J. Fabian, PRB 93 155104 (2016)
[3] T. Frank, M. Gmitra, and J. Fabian, PRB 93 155142 (2016)

MA 63.10 Fri 12:15 POT 251

HgTe shells on CdTe nanowires — •Jan Hajer, Maximilian Kessel, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut, EP3, Am Hubland, 97074 Würzburg

Topological insulator nanowires in proximity to a superconductor are in research focus of condensed matter physics. Hosting Dirac-like surface states with high spin-orbit coupling, they are a possible platform for p-wave superconductivity and Majorana bound states.

In our work we investigate low temperature charge transport in quasi one-dimensional HgTe. Vapor-liquid-solid grown CdTe nanowires of high crystal quality serve as a substrate for epitaxial HgTe overgrowth. The core-shell heterostructures show residual strain, expected to transform the semi-metallic HgTe shell to a quasi one-dimensional topological insulator. Charge transport with proximitized superconductors indicates a high interface quality giving rise to the observation of multiple Andreev reflections and an induced supercurrent.

MA 64: Poster 1

Time: Friday 9:30–13:00 Location: P2-EG

MA 64.1 Fri 9:30 P2-EG

Emergent Momentum-Space Skyrmion Texture on the Surface of Topological Insulators — Narayan Mohanta[1], Arno P. Kampf[2], and •Thilo Kopp[3] — [1]Center for Electronic Correlations and Magnetism, Theoretical Physics III, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Center for Electronic Correlations and Magnetism, Experimental Physics VI, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [3]Center for Electronic Correlations and Magnetism, Theoretical Physics III, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

The quantum anomalous Hall effect has been theoretically predicted and experimentally verified in magnetic topological insulators. In addition, the surface states of these materials exhibit a hedgehog-like "spin" texture in momentum space. Here, we apply the previously formulated low-energy model for Bi_2Se_3, a parent compound for magnetic topological insulators, to a slab geometry in which an exchange field acts only within one of the surface layers. In this sample set up, the hedgehog transforms into a skyrmion texture beyond a critical exchange field. This critical field marks a transition between two topologically distinct phases. The topological phase transition takes place without energy gap closing at the Fermi level and leaves the transverse Hall conductance unchanged and quantized to $e^2/2h$. The momentum-space skyrmion texture persists in a finite field range. It may find its realization in hybrid heterostructures with an interface between a three-dimensional topological insulator and a ferromagnetic insulator.

MA 64.2 Fri 9:30 P2-EG

The Influence of the Dzyaloshinskii-Moriya (DM) interactions on the magnon spectrum in Cu_2OSeO_3 — •Y. Onykiienko[1], Y. Tymoshenko[1], D. Inosov[1], P. Portnichenko[1], A. Schneidewind[2], P. Cermak[2], A. Henschel[3], and M. Schmidt[3] — [1]Institute of Solid State Physics, TU Dresden, D-01069 Dresden, Germany — [2]Jülich Center for Neutron Science (JCNS), Garching, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, German

Cu_2OSeO_3 is an insulating helimagnetic multiferroic material which hosts a skyrmion phase. It has non-centrosymmetric space group ($P2_13$) similar to the B20 skyrmion compounds (e.g. MnSi, FeGe), but with a much more complex structure. Recent studies reveal good agreement between TOF neutron scattering data and theoretical predictions that suggest a spin model with up to 5 nearest-neighbor Heisenberg exchange interactions neglecting antisymmetric DM terms responsible for the helical ground state. Taking them into account leads to corrections that are smaller than the resolutions of most available instruments. However a significant deviation has been found in the spin-wave spectrum, presumably, caused by the DM interactions.

By means of the cold neutron TAS we observed the gap of about 1.6 meV in the magnetic spectrum which is absent in the previously reported spin-wave model. In addition we established magnon branch splitting at high symmetry points of the reciprocal space. Both observations can be explained in the frame of the linear spin-wave theory by taking into account theoretically predicted DM interactions.

MA 64.3 Fri 9:30 P2-EG

Dzyaloshinskii-Moriya Interaction in FeGe samples: Ferromagnetic resonance and micromagnetic simulations — •Thomas Feggeler[1], Ralf Meckenstock[1], Zi-An Li[1], Detlef Spoddig[1], Iliya Radulov[2], Konstantin Skokov[2], Oliver Gutfleisch[2], and Michael Farle[1,3] — [1]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [2]Institut für Materialwissenschaft, TU Darmstadt, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany — [3]Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russian Federation

We perform temperature and angular dependent Ferromagnetic Resonance (FMR) measurements (X-band) on bulk FeGe and FeGe in confined geometries. Results of a polycrystalline bulk B20-FeGe sample (diameter 3.78 mm, thickness 0.78 mm), manufactured by high pressure high temperature synthesis, show Dyson-shaped resonances with an angular dependent resonance field between 345 mT and 322 mT at 294 K. Cooling the sample to 152 K reveals several additional resonances in good agreement to [1]. An angular dependence of the resonances could not be detected below 280 K. FMR-Measurements of FeGe samples in confined geometries (6 μm x 200 nm x 20 nm) show several resonances in a small angular range between 270 K and 280 K, indicating a complex standing wave pattern as discussed in [2]. Additionally, we will show the results of supplementary static and dynamic micromagnetic simulations of the bulk and confined geometry FeGe. [1] Haraldson, S., et al. JMR, 1972. 8(3): p. 271-273. [2] Zingsem, B.W., et al., arXiv:1609.03417, 2016: p. 1-26.

MA 64.4 Fri 9:30 P2-EG

Thickness dependence of the appearance of the skyrmion phase in FeGe: A TEM study — •Sebastian Schneider[1,2], Darius Pohl[1], Ulrich K. Rössler[3], Marcus Schmidt[4], Axel Lubk[5], Thomas Gemming[6], Kornelius Nielsch[1,7], Sebastian T. B. Goennenwein[2], and Bernd Rellinghaus[1] — [1]IFW Dresden, Institute for Metallic Materials, Dresden — [2]TU Dresden, Institute of Solid State Physics, Dresden — [3]IFW Dresden, Institute for Theoretical Solid State Physics, Dresden — [4]Max-Planck Institute for Chemical Physics of Solids, Research Field Chemical Metals Science, Dresden — [5]IFW Dresden, Institute for Solid State Research, Dresden — [6]IFW Dresden, Institute for Complex Materials, Dresden — [7]TU Dresden, Institute of Materials Science, Dresden

Novel nanoscale magnetic phenomena such as skyrmions cause a steadily increasing demand for ultra-high resolution quantitative magnetic characterization. Here, transmission electron microscopy (TEM) provides the possibility to locally correlate the magnetic properties of the sample with its structure and chemical composition thereby providing for a more complete picture of the underlying physics. We investigate the skyrmion phase of a thin lamella of a FeGe single crystal in Lorentz-TEM (LTEM). Corresponding thickness measurements of sample areas under investigation reveal a breakdown of the skyrmion phase below film thicknesses of 40 nm. We furthermore report on the lateral components of the magnetization in skyrmions by applying the transport of intensity equation to focal series of LTEM images.

MA 64.5 Fri 9:30 P2-EG

Investigation of the Influence of the Skyrmion Radius on Real-Time Skyrmion Trajectories and the Skyrmion Hall Effect — •P. Bassirian[1], K. Litzius[1,2], I. Lemesh[3], B. Krüger[1], L. Caretta[3], K. Richter[1], F. Büttner[3], J. Förster[2], R. M. Reeve[1], M. Weigand[2], I. Bykova[2], H. Stoll[2], G. Schütz[2], G. S. D. Beach[3], and M. Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [2]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [3]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Magnetic skyrmions are promising candidates for new data storage and information processing devices, due to their topologically stabilized spin structure and their recently demonstrated efficient spin orbit torque driven dynamics. Recent experimental studies have shown a deviation of the skyrmion trajectories with respect to the direction of the current flow [1,2]. This deviation angle between motion direction and current direction is quantified as the skyrmion Hall angle (SHA). We have observed a dependence of the SHA on the size of the skyrmion [2,3], which allows us to manipulate the skyrmion trajectory by engineering the skyrmion size. We investigate the response of the skyrmion radius on an external magnetic field to obtain the influence of materials properties and skyrmion size on the skyrmion Hall effect.

[1] Jiang, W. et al. Nat. Phys. (online) DOI:10.1038/nphys3883 (2016). [2] Litzius, K. et al., Nature Physics (in press 2016), arxiv:1608.07216. [3] Woo, S. et al. Nat. Mater. 15, 501-506 (2016).

MA 64.6 Fri 9:30 P2-EG

Antiferromagnetic domain wall motion in the presence of spin-polarized current and temperature gradient — •Olena Gomonay, Kei Yamamoto, and Jairo Sinova — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Antiferromagnets (AF) are promising materials for spintronic applications because they show fast magnetic dynamics and low susceptibility with respect to magnetic fields. Application of AF as information storage devices implies fast and reliable switching between different states. In this presentation we focus on the domain wall motion as a main mechanism of the switching. We consider combined effects of the temperature gradient and spin current on the AF domain wall motion. We demonstrate that spin current splits the effective temperatures of the magnon gas in different domains and thus induces the magnon current equivalent to the thermal one. This mechanism can add to or compete with the entropic mechanism, that results from the temperature gradient. We show that tailoring of the device geometry can enhance or suppress the effective force that sets the AF domain wall into motion. This effect opens a way to manipulate a domain wall position in the presence of temperature gradient.

MA 64.7 Fri 9:30 P2-EG

Co-sputtered PtMnSb thin films and Pt/PtMnSb bilayers for spin-orbit torque investigations — •Jan Krieft[1], Johannes Mendil[2], Myriam H. Aguirre[3], Can O. Avci[4], Christoph Klewe[5], Karsten Rott[1], Jan-Michael Schmalhorst[1], Günter Reiss[1], Pietro Gambardella[2], and Timo Kuschel[1,6] — [1]CSMD, Bielefeld University, Germany — [2]Department of Materials, ETH Zürich, Switzerland — [3]Universidad de Zaragoza, Spain — [4]MIT, Boston, USA — [5]ALS, Berkeley, USA — [6]University of Groningen, The Netherlands

The manipulation of magnetization by the use of spin-orbit torques (SOTs) has recently been extensively studied.[1,2] Particular attention is paid to non-centrosymmetric systems with space inversion asymmetry, where SOTs emerge even in single-layer materials.[3,4] Here, we report on the growth and epitaxial properties of the SOT material PtMnSb thin films and PtMnSb/Pt bilayers deposited on MgO(001) substrates by dc magnetron co-sputtering at high temperature in ultra-high vacuum. The film properties were investigated by x-ray diffraction, x-ray reflectivity, atomic force microscopy, and electron microscopy, in order to provide information on the film structure, stoichiometry, and surface topography.

[1] I. M. Miron et al., Nature 476, 189 (2011).
[2] L. Neumann et al., Appl. Phys. Lett. 109, 142405 (2016).
[3] T. Jungwirth et al., Nat. Nanotechn. 11, 231 (2016).
[4] P. Wadley et al., Science 351, 587 (2016).

MA 64.8 Fri 9:30 P2-EG

Investigating the skyrmion breathing mode using conjugate variables — •Benjamin F. McKeever[1], Artem G. Abanov[2], and Karin Everschor-Sitte[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Texas A&M University, College Station, Texas, USA

The understanding and subsequent manipulation of properties of magnetic skyrmions is an important challenge for their use in future energy-efficient devices. Different excitations of single skyrmions have been observed and here we consider the so called “breathing mode” in which the core region of the skyrmion periodically grows and shrinks. We analyse the breathing mode in analogy to how it has been studied in quantum Hall systems, namely by using a phenomenological theory of conjugate variables.

MA 64.9 Fri 9:30 P2-EG

GMR films with crossed anisotropies for perpendicular field measurements — •Fabian Ganss[1,3], Wolfgang Raberg[2], Sebastian Luber[2], Sri Sai Phani Kanth Arekapudi[3], Olav Hellwig[3,4], and Manfred Albrecht[1] — [1]Institute of Physics, Augsburg University, Augsburg — [2]Infineon Technologies AG, Neubiberg — [3]Institute of Physics, Chemnitz University of Technology, Chemnitz — [4]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden

As 3-dimensional field sensors require one part being susceptible to perpendicular fields, thin film GMR stacks with a linear and reversible response to such fields are of interest for the development of monolithic sensor devices. Stacks with such a behavior can be achieved by combining a *pinning layer* with perpendicular *easy axis* and a *free layer* with perpendicular *hard axis*. Furthermore, the stray field of the pinning layer can be minimized and its coercivity enhanced if a ferrimagnet (or antiferromagnet) is used. For the present study, Tb_xCo_{100-x} alloys have been chosen as the pinning layer material and $Ni_{81}Fe_{19}$ for the free layer. The single layers have been characterized by SQUID-VSM measurements, the complete layer stack by magneto-resistance measurements. Initial films confirm the expected behavior and exhibit a change in resistivity of 5% in a field range of 10 kOe. Further films will be optimized regarding their magnetic and electric properties. They shall be micro-structured then and equipped with bottom contacts through the substrate.

MA 64.10 Fri 9:30 P2-EG

Magnetic susceptibility and phase transitions in the B20 helical magnet $Mn_{1-x}Co_xGe$ — •Patrick Strauss[1], Evgeny Altynbaev[2], Sven-Arne Siegfried[3], Evgeny Moskvin[2], André Heinemann[3], Ludmila Fomicheva[4], Anatoly Tsvyashchenko[4], Sergey Grigoriev[2], and Dirk Menzel[1] — [1]IPKM, TU Braunschweig, Germany — [2]PNPI, Gatchina and Saint-Petersburg State University, Russia — [3]Helmholtz-Zentrum Geesthacht, Germany — [4]IHPP, Troitsk, Russia

The non-centrosymmetric transition metal silicides and germanides crystallizing in the cubic B20 structure are well-known for the competing Heisenberg and Dzyaloshinskii-Moriya (DM) interactions leading to incommensurate helical spin structures. The germanides stand out for their relatively high ordering temperatures (278 K for FeGe, e.g.) and complex magnetic phase diagrams. We present a distinct magnetic characterization of the solid solution $Mn_{1-x}Co_xGe$ measured by SQUID magnetometry. The ordering temperature decreases from $T = 200$ K for MnGe to $T = 25$ K for $Mn_{0.05}Co_{0.95}Ge$. Small-angle neutron scattering (SANS) measurements imply that the helical spin structure is driven by RKKY exchange for $x < 0.45$. In this regime, hysteresis measurements show low anisotropy. In contrast, the exchange is dominated by DM interaction for $x > 0.45$, which can be supported by an enhanced magnetic anisotropy derived from the magnetization curves. In the high-field regime magnetic transitions are observed which are discussed in the context of the results of the SANS measurements.

MA 64.11 Fri 9:30 P2-EG

Thermodynamics of the Kagome lattice with arbitrary spin $S \geq 1/2$ — •Patrick Müller, Andreas Zander, and Johannes Richter — Institut für Theoretische Physik, Universität Magdeburg - 39016 Magdeburg, Germany

One of the most prominent and at the same time frequently discussed model with a frustration induced highly degenerated classical ground-state (GS) manifold is the Heisenberg antiferromagnet (HAFM) on the Kagome lattice. The geometry of the lattice, which consists of corner-sharing triangles, suppresses a conventional ordering of the spins at absolute zero. Although it is clear that for $S = 1/2$ there is no magnetic long-range order, the precise nature of the quantum spin-liquid is still under debate. We use the spin-rotation invariant Green's function method (RGM) with an additional input (ground-state energy data of the Coupled-Cluster-Method (CCM)[1]) to study the temperature dependence of the magnetic structure factor $S_{\mathbf{Q}}$, the susceptiblity χ_0, the specific heat C_V, the correlation length $\xi_{\mathbf{Q}}$ and the correlation functions $\langle S_0 S_{\mathbf{R}} \rangle$ for $S \geq 1/2$. Moreover, we compare the RGM data with the corresponding high-temperature expansion (HTE) data [2]. [1] O. Götze, D. J. J. Farnell, R. F. Bishop, P. H. Y. Li, and J. Richter, Phys. Rev. B **84**, 224428, (2011). [2] A. Lohmann, H.-J. Schmidt, and J. Richter, Phys. Rev. B **89**, 014415, (2014). [3] B. H. Bernhard, B. Canals, and C. Lacroix, Phys. Rev. B **66**, 104424, (2002). [4] D. Schmalfuss, J. Richter, and D. Ihle, Phys. Rev. B **70**, 184412, (2004).

MA 64.12 Fri 9:30 P2-EG

Study of hysteresis phenomena in spin crossover systems — •Raluca-Maria Stan, Roxana Gaina, and Cristian Enachescu — Faculty of Physics, Alexandru Ioan Cuza University of Iasi, Iasi, Romania

Spin transition molecular magnets are inorganic compounds, commutable between two states in thermodynamic competition: the low spin state (LS) and the high spin state (HS). When the intermolecular interactions are larger than a threshold, the commutation is accompanied by various hysteresis, such as thermal, light induced or pressure hysteresis, property at the base of applications for information storage and numerical display. Here we shall study the thermal hysteresis (TH) and light induced thermal hysteresis (LITH) in the case of $Fe(bbtr)_3(ClO_4)_2$ spin crossover compound. While the TH obtained at higher temperature (above 100K) is rate-independent, the LITH, obtained at low temperatures while irradiating the compound with a laser beam, shows a strong rate dependence (kinetic effects). Using the First Order Reversal Curves (FORC) method, which is well known for its capacity to provide information about the intrinsic properties of compounds showing hysteresis, we have qualitatively analyzed the kinetic effects. Then, in order to obtain a further quantitative analysis of the phenomena, the Mean Field model was used to simulate the observed behavior and an algorithm to disentangle between the static and dynamical effects in LITH was proposed.

MA 64.13 Fri 9:30 P2-EG

Phase diagram of $La_{1-x}Sr_xMnO_3/SrTiO_3$ epitaxial thin films — •Danny Schwarzbach[1], Markus Jungbauer[2], and Vasily Moshnyaga[2] — [1]Institut für Materialphysik, Georg-August-Universität Göttingen — [2]Erstes Physikalisches Institut, Georg-August-Universität Göttingen

Charge, spin and orbital interface reconstructions in $LaMnO_3/SrMnO_3$ superlattices (SLs) result in a novel interfacial high-temperature ferromagnetism. We present a complex study of parent mixed-valence $La_{1-x}Sr_xMnO_3$ (LSMO(x), $x = 0-1$) film system, which enables us to model and quantify magnetic coupling between FM and AFM phases in SLs. The LSMO(x) films ($d = 40$ nm) were epitaxially grown by metalorganic aerosol deposition technique on STO substrates with (001) and (111) orientations. The LSMO(x)/STO(001) films with $x \leq 0.6$ were found to be fully strained, whereas those of LSMO(x)/STO(111) start to relax for $x > 0.4$. The tensile strain in the (001)-plane favors an AFM ordering of the A-type due to orbital polarization of $(x^2 - y^2)$ orbitals of Mn ions. Therefore, the FM/AFM crossover is shifted to higher values of Sr-doping, x, for the films grown on STO(111) as compared to those on STO(001) substrate. Using in-situ optical ellipsometry we were able to monitor and control substrate temperature, film thickness and growth mode itself. Moreover, the acquired phase shift between p- and s-polarized reflected waves was found to depend on the charge density (Mn^{3+}/Mn^{4+} ratio), helping us to quantify the FM/AFM crossover.

Financial support from DFG (SFB1073, TP B04) is acknowledged.

MA 64.14 Fri 9:30 P2-EG

Optically detected magnetic resonances for different magnetic phases in CuB_2O_4 — •Henning Moldenhauer[1], Vitalii Yu. Ivanov[2], Jörg Debus[1], Dennis Kudlacik[1], Roman Pisarev[3], Dmitri R. Yakovlev[1,3], and Manfred Bayer[1,3] — [1]Experimentelle Physik 2, Technische Universität Dortmund, Dortmund, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland — [3]Ioffe Institute, Russian Academy of Sciences, St. Petersburg, Russia

A recent study has shown a direction dependent photoluminescense (PL) of up to 70% in CuB_2O_4, that means an asymmetry between the opposite directions of the PL emission from the crystal. Moreover, the non-centrosymmetric tetragonal CuB_2O_4 consists of two sublattices with different magnetic ordering; magnetic phase transitions occur at about 9 K and 21 K. We investigate the magnetic phase transitions and the spatial PL emission asymmetry using the optically detected magnet resonance technique with 60 GHz microwave radiation. We demonstrate strong dependences on the magnetic field direction and microwave radiation power for the spectrally selected PL transitions of the antiferromagnetically ordered sublattice. In that way, we aim at enhancing the understanding of the energy and spin level structure of the sublattices in CuB_2O_4 at different temperature ranges thus underlying its highly interesting optical and magnetic properties.

MA 64.15 Fri 9:30 P2-EG

Measuring the spin-spin interaction on few doubly labeled proteins using NV-centers in diamonds — •Bastian Kern[1], Lukas Schlipf[1], Kebiao Xu[1,2,3], Amit Finkler[3], Markus Ternes[1], Jörg Wrachtrup[1,3], and Klaus Kern[1,4] — [1]MPI for Solid State Research, D-70569 Stuttgart, Germany — [2]CAS Key Laboratory of Microscale Magnetic Resonance, USTC, 230026 Hefei, China — [3]3. Physikalisches Institut, Universität Stuttgart, D-70569 Stuttgart, Germany — [4]Institut de Physique de la Matière Condensée, EPFL, CH-1015 Lausanne, Switzerland

Electron Paramagnetic Resonance (EPR) measurements of proteins labeled with two nitroxide spins have enabled the structural analysis of these proteins with sub-nm spatial resolution [1], with the main drawback of of large numbers of spins required for the experiment ($\sim 10^{10}$ spins). Using an atomic scale sensor can lower this limit significantly. A system perfectly suited for this task are single nitrogen vacancy (NV) centers in diamonds [2]. For the first we time measure the interaction between nitroxide spin labels on doubly labeled proteins while only probing few (∼1-100) molecules with a triple electron resonance scheme at cryogenic temperatures: The dipolar interaction between the two spins on the protein, which is related to their distance, is detected using a nearby third electron spin of an NV center. These results show the capability of NV spin spectrometry in determining the distance between spin labels, using only few molecules.

[1] O. Duss et al, Nat. Comm. 5, 3669 (2014); [2] F. Jelezko, J. Wrachtrup, Phys. Stat. Sol. 203, 13, 3207-3225 (2006)

MA 64.16 Fri 9:30 P2-EG

Magnetoelectric properties in oxidized-graphenic nanoplatelets and thin films obtained from bamboo — •Katherine Gross[1], Jhon Jairo Prias-Barragán[2,3], Luc Lajaunie[4], Raul Arenal[4], Hernando Ariza-Calderón[2], and Pedro Prieto[1] — [1]CENM, Universidad del Valle, Colombia — [2]IIS, Universidad del Quindio, Colombia — [3]EITP, Universidad del Quindio, Colombia — [4]LMA, INA, Universidad de Zaragoza, Zaragoza, Spain

We employed a novel and cost-effective pyrolytic method to synthetize oxidized-graphenic nanoplatelets (OGNP) and thin films using bamboo, which is a cheap and highly renewable natural source. We have studied the magnetic response by systematically varying the crystal structure and topological defects. The crystal structure and the surface topography is modified by increasing the carbonization temperature in a range of 473K to 973K. At 973K OGNP present a higher ordered crystalline graphite structure and a sp2 fraction of 87 percent. OGNP show ferromagnetic order and low coercivity at room temperature. Magnetic properties are correlated with the presence of topological defects due to a natural formation of islands during the carbonization process. Magnetic force microscopy gives direct evidence for local ferromagnetic order at the topological defects. Temperature dependence on conductivity of the thin films showed typical semiconductor behavior, which could be described by the Mott 3D variable-range hopping mechanism. Hysteretic negative magnetoresistance (MR) was found in thin films, which confirms the intrinsic nature of the observed ferromagnetism. At 300 K the maximum MR is about 2 percent.

MA 64.17 Fri 9:30 P2-EG

PLY-Cu for organic MTJs — •Christian Denker[1], Pavan K. Vardhanapu[2], Bikash Das Mohapatra[4], Ulrike Martens[1], Heba Mohammad[1], Mykola Medvidov[3], Christiane Helm[1], Swadhin Mandal[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Germany — [2]IISER, Kolkata, India — [3]ZIK HIKE, Universität Greifswald, Germany. — [4]NISER, Bhubaneshwar, India

Phenalenyl (PLY) based molecules are promising candidates for spintronics application. Attempts to use open shell PLY molecules have been unsuccessful due to their instability. Mandal and coworkers took a new route for PLY-based molecules with a closed shell ground state. For example, zinc methyl phenaleny (ZMP) shows a magnetoresistance of 20% even near room temperature [Nature 493 509 (2013)].

Motivated by these results, we are investigating a new closed shell molecule, PLY with Cu complex, for its spintronics suitablity. Thin film are deposited by thermal evaporation maintaining its chemical properties as shown by Fourier transform infrared spectroscopy (FTIR). Ferromagnet/PLY-Cu/ferromagnet heterostructure devices are fabricated by deposition through an in-situ mask under different angles. These devices are characterized by atomic-force microscopy (AFM), scanning electron microscopy (SEM) and magneto-resistance measurements.

MA 64.18 Fri 9:30 P2-EG

Spin transport across antiferromagnetic IrMn thin films — •Joel Cramer[1,2], Bowen Dong[1,2], Samridh Jaiswal[1,3], Felix Fuhrmann[1], Gerhard Jakob[1], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Singulus Technologies AG, Hanauer Landstraße 103, 63796 Kahl am Main, Germany

Recently, the investigation of magnonic spin currents in antiferromagnetic materials has gained interest. We present measurements on the spin transmission of metallic, antiferromagnetic iridium manganese (IrMn) thin films in yttrium iron garnet (YIG)/IrMn/Pt tri-layers. For this purpose, spin Seebeck (SSE) as well as spin Hall magnetoresistance (SMR) measurements have been performed. When measured as a function of temperature, a signal maximum appears in the temperature profile of the SSE amplitude with the temperature of the maximum depending on the IrMn thickness. Below this temperature, the signal decreases rapidly and is eventually suppressed at temperatures, at which YIG/Pt reference samples still show a clearly measurable SSE voltage. The same trend is observed in the temperature dependent SMR measurements. In insulating AFMs spin transmission has been studied[1,2] and is explained by the AFM layer undergoing the phase transition from the paramagnetic into the antiferromagnetic state. To check for this possibility, temperature dependent SQUID magnetometry measurements are performed. [1] Qiu et al., Nat. Comm. 7, 12670 (2016) [2] Prakash et al., Phys. Rev. B 94, 014427 (2016)

MA 64.19 Fri 9:30 P2-EG

Thermoelectrical characterization of MnSi nanowires — •Alexander Fernández Scarioni[1], David Schroeter[2], Xiukun Hu[1], Sibylle Sievers[1], Dirk Menzel[2], Stefan Süllow[2], and Hans W. Schumacher[1] — [1]Physikalish-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

In bulk samples, the chiral magnet MnSi shows a skyrmion phase or so called A-phase in a small temperature-magnetic field range. With decreasing this A-phase expands and the *skyrmion state* becomes more stable. One way to study this A-phase has been through measurements of the Hall effect where the topological part (topological hall effect) shows evidence of the existence of the skyrmion phase in bulk and thin film MnSi.

We propose a different method to study this A-phase, using the anomalous Nernst effect (ANE), the thermoelectric analogon to the anomalous Hall effect. For this purpose we fabricated MnSi thin films using molecular beam epitaxy and then structure them down to nanowires using electron beam lithography and sputter etching. A temperature gradient is generated by a platinum microheater placed next to the MnSi nanowire. The thermoelectric voltage generated in the wire allows us to detect the average magnetization state of the wire without applying a current.

First ANE data of our MnSi nanowires in different magnetic phases will be discussed.

MA 64.20 Fri 9:30 P2-EG

Damping of parametrically excited magnons in the presence of the longitudinal spin Seebeck effect — •Thomas Langner[1], Akihiro Kirihara[2], Alexander A. Serga[1], Burkard Hillebrands[1], and Vitaliy I. Vasyuchka[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]IoT Devices Research Laboratories, NEC Corporation, Tsukuba, Japan

The impact of the longitudinal spin Seebeck effect (LSSE) on the magnon damping in magnetic-insulator/nonmagnetic-metal bilayers was recently discussed in several reports. However, results of those experiments can be blurred by multimode excitation within the measured linewidth. In order to avoid possible intermodal interference, we investigated the damping of a single magnon group in a platinum covered Yttrium Iron Garnet (YIG) film by measurement of the threshold of its parametric excitation. Both dipolar and exchange spin-wave branches were probed. It turned out that the LSSE-related modification of spin-wave damping in a micrometer-thick YIG film is too weak to be observed in the entire range of experimentally accessible wavevectors. At the same time, the change in the mean temperature of the YIG layer, which can appear by applying a temperature gradient, strongly modifies the damping value. Financial support by DFG within SPP 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 64.21 Fri 9:30 P2-EG

Magneto-optic detection of spin Seebeck effect in Au/YIG and Cu/YIG bilayers at picosecond time scale — Johannes Kimling[1], Gyung-Min Choi[2], Jack T. Brangham[3], •Tristan Matalla-Wagner[4], Torsten Huebner[4], Timo Kuschel[4,5], Fengyuan Yang[3], and David G. Cahill[1] — [1]University of Illinois, Urbana, USA — [2]Korea Institute of Science and Technology, Seoul, Korea — [3]The Ohio State University, Columbus, USA — [4]CSMD, Bielefeld University, Germany — [5]University of Groningen, The Netherlands

A temperature gradient perpendicular to the plane of $Y_3Fe_5O_{12}$ (YIG) / Pt bilayers drives an out-of-plane spin current in the YIG and at the YIG/Pt interface (longitudinal spin Seebeck effect), which is injected into the Pt. The inverse spin Hall effect in Pt converts the spin current into a transverse charge current and, thus, a charge voltage can be measured. However, a magnetic proximity effect (MPE) in Pt can occur, that allows for the anomalous Nernst effect, which has the same symmetry as the LSSE and, therefore, can contribute to the measured voltage as a parasitic side effect. To detect the LSSE without any MPE side effects, additional techniques such as magneto-optic means can be applied. Here, we present LSSE measurements using the time-resolved magneto-optic Kerr effect. Our results indicate angular-momentum transfer across YIG/Cu and YIG/Au interfaces on a picosecond time scale [1].

[1] J. Kimling et al., arxiv: 1608.00702

MA 64.22 Fri 9:30 P2-EG

Temperature gradient simulations in laser-induced tunnel magneto-Seebeck experiments — •Torsten Huebner[1], Alexander Boehnke[1], Andy Thomas[2], Günter Reiss[1], Markus Münzenberg[3], and Timo Kuschel[1,4] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]IMW, IFW, Dresden, Germany — [3]IFP, Greifswald University, Germany — [4]University of Groningen, The Netherlands

The Seebeck coefficient of a magnetic tunnel junction (MTJ) changes depending on the magnetization alignment of its electrodes and, thus, the measured thermovoltage changes as well. This effect is know as the tunnel magneto-Seebeck (TMS) effect and has been studied in many systems, experimentally [1-4] as well as theoretically [5,6]. Naturally, knowledge about the temperature gradient is crucial. Since this quantity is not accessible experimentally, we use FEM simulations to draw conclusions about the heat distribution. Here, we present a detailed study of the temperature gradient depending on the barrier thickness including the uncertainty of the thermal conductivity [7].

[1] Walter et al., Nat. Mater. 10, 742 (2011)
[2] Liebing et al., Phys. Rev. Lett. 107, 177201 (2011)
[3] Boehnke et al., Rev. Sci. Instrum. 84, 063905 (2013)
[4] Huebner et al., Phys. Rev. B 93, 224433 (2016)
[5] Czerner et al., J. Appl. Phys. 111, 07C511 (2012)
[6] Heiliger et al., Phys. Rev. B 87, 224412 (2013)
[7] Zhang et al., Phys. Rev. Lett. 115, 037203 (2015)

MA 64.23 Fri 9:30 P2-EG

A systematical study on the anomalous Hall and Nernst effect in Co/Pd multilayers — •Oliver Reimer[1], Daniel Meier[1], Jan-Michael Schmalhorst[1], Guenter Reiss[1], and Timo Kuschel[1,2] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]University of Groningen, The Netherlands

In spin caloric experiments the unambigous determination of the longitudinal spin Seebeck effect (LSSE) produced by metallic magnetic films or multilayers is challenging due to the simultaneously occuring anomalous Nernst effect (ANE). Thus a new methodology that can eliminate parasitic effects like the ANE is necessary. Studies of the anomalous Hall effect (AHE), i.e. the charge current based counterpart of the ANE in perpendicular magnetized Co/Pd multilayers revealed a sign change of the AHE [1,2]. The sign of the AHE change depends in particular on the temperature and the Co thickness of the multilayer. We present a systematic study on Co/Pd multilayers, which compares the AHE and the ANE for samples with varying Co thickness and base temperature within one experiment. If a sign change in the ANE could be detected, LSSE experiments could be tuned in a way that no ANE contributions would occur. This opens a way for unambiguously detecting the LSSE and for deepening the knowledge of spin-related transport phenomena.

[1] V. Keskin et al., Appl. Phys. Lett. 102, 022416 (2013)
[2] X. Kou et al., J. Appl. Phys. 112, 093915 (2012)

MA 64.24 Fri 9:30 P2-EG

Spin disorder effect on the electronic properties of NiMnSb — •Roman Kováčik, Phivos Mavropoulos, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

An important contribution to the spin-caloric transport properties in magnetic materials at elevated temperatures is the formation of a spin-disordered state due to the local moment fluctuations. We investigate how the spin disordered state affects the spectral function, self energy and transport properties of NiMnSb, a prototypical half-metallic ferromagnet. The electronic structure of NiMnSb is calculated within the full-potential Korringa-Kohn-Rostoker (KKR) Green function framework [1]. The Monte-Carlo methodology is used to simulate the effect of temperature induced spin disorder and the set of spin-disordered configurations is fed back in the KKR method to obtain statistical average of the relevant material properties [2]. As an example, we find qualitative differences between the spectral function projected on Ni and Mn sites around the Curie temperature. In comparison to the $T = 0$ K state, the majority spin spectral function only broadens at Ni site whereas it acquires rather rich landscape at Mn site. In the minority spin, the most interesting outcome is the shift of the prominent peak away from the Γ-point at Ni site and to higher energy across the Fermi level at Mn site. Support from the DFG (SPP 1538) and JARA-HPC (jara0051) is gratefully acknowledged. [1] N. Papanikolaou *et al.*, J. Phys. Condens. Matter 14, 2799 (2002), also see: www.kkr-gf.org. [2] R. Kováčik *et al.*, Phys. Rev. B 91, 014421, (2015).

MA 64.25 Fri 9:30 P2-EG

Non-local magnetoresistance by magnon transport in various magnetic insulating garnets — •Nynke Vlietstra[1], Kathrin Ganzhorn[1,2], Tobias Wimmer[1,2], Stephan Geprägs[1], Rudolf Gross[1,2,3], Sebastian T.B. Goennenwein[1,2,3,4], and Hans Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), München, Germany — [4]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany

In recent years the ferrimagnetic insulating material yttrium iron garnet (YIG) has been intensively studied, mostly in combination with an adjacent few-nm-thick platinum (Pt) layer. Besides the local generation and detection of pure spin-currents in such a bilayer system, it was shown in 2015 that it is also possible to generate non-local electrical signals by transporting spin-information through the electrical insulating YIG layer by diffusion of incoherent magnons (quantized spin-waves) [1,2]. We study this non-local magnon transport, by electrical injection as well as by thermal excitation of magnons, for various magnetic insulating garnets. By measuring as a function of temperature and both the direction and magnitude of an applied magnetic field, we investigate the influence of various magnetic structures on the magnon generation, transport and non-local detection.

[1] L. Cornelissen et al., Nat. Phys. **11**, 1022 (2015)
[2] S. T. B. Goennenwein et al., Appl. Phys. Lett. **107**, 172405 (2015)

MA 64.26 Fri 9:30 P2-EG

Spin Hall Magnetoresistance in Canted Ferrimagnets — •Richard Schlitz[1,2,3], Kathrin Ganzhorn[1,3], Matthias Opel[1], Matthias Althammer[1,3], Stephan Geprägs[1], Hans Huebl[1,3,4], Rudolf Gross[1,3,4], and Sebastian T. B. Goennenwein[1,2,3,4] — [1]Walther-Meißner-Institut, Garching, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Technische Universität München, Garching, Germany — [4]Nanosystems Initiative Munich, München, Germany

The spin Hall magnetoresistance (SMR) results from the interplay of spin and charge currents and, thus, is a valuable tool for studying the spin structure in ferromagnetic insulator (FMI)|normal metal bilayers.

The accepted model for SMR suggests that the metal's resistance only depends on the direction of the net magnetization of the FMI. To test this, we study rare earth iron garnet|platinum (REIG|Pt) hybrid structures featuring different magnetic sublattices with a magnetic compensation point. Thus, we can investigate the SMR in a non-collinear spin configuration where the sublattice magnetizations are not aligned with one another or the external magnetic field.

In contrast to the predictuion of present models, our studies reveal a dependence of the SMR on the magnetic sublattice orientations. In particular, we observe a sign inversion of the SMR close to the magnetic compensation temperature. We discuss these findings in comparison to atomistic spin simulations and X-ray magnetic circular dichroism experiments[1].

[1] K. Ganzhorn *et al.*, Physical Review B **94**, 094401 (2016)

MA 64.27 Fri 9:30 P2-EG

Spin Hall magnetoresistance using antiferromagnetic insulators — •Johanna Fischer[1,2], Stephan Geprägs[1], Kathrin Ganzhorn[1,2], Matthias Opel[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

The phenomena of pure spin currents have mainly been investigated in ferromagnetic insulators/normal metal hybrid structures and give rise to new spintronic effects like the spin Hall magnetoresistance (SMR).[1] As ferromagnets are very sensitive to external magnetic fields, devices based on antiferromagnetic materials may be a better solution for future spintronic applications. We study the possible SMR in heterostructures of epitaxially grown antiferromagnets covered by a thin Pt layer. We measure the angle dependent magnetoresistance in magnetic fields up to 7 T at different temperatures for three rotation planes relative to the field orientation. We discuss the SMR amplitude in terms of the newly discovered sub-lattice SMR model. This work is supported by the DFG via SPP 1538.

[1] M. Althammer et al., Phys. Rev. B **87**, 224401 (2013)

MA 64.28 Fri 9:30 P2-EG

Effect of quantum tunneling on spin Hall spin-transfer torque and spin Hall magnetoresistance — •Wei Chen[1], Seulgi Ok[1,2], Manfred Sigrist[1], Jairo Sinova[3], and Dirk Manske[4] — [1]ETH Zurich, Switzerland — [2]University of Zurich, Switzerland — [3]University of Mainz, Germany — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany

In the normal metal/ferromagnetic insulator bilayer (such as Pt/YIG) and the normal metal/ferromagnetic metal/oxide trilayer (such as Pt/Co/AlOx), the spin injection can be achieved by the spin Hall effect in the normal metal. We demonstrate that the quantum tunneling of spin without transferring charge is a major mechanism for the spin Hall effect induced spin-transfer torque observed in these thin films. In addition, this quantum tunneling mechanism in combination with the spin diffusion effect in the normal metal well-explain the spin Hall magnetoresistance obsered in these thin films. Our minimal model expresses these quantities in terms of generic material properties such as interface s-d coupling, insulating gap, and layer thickness, rendering an inexpensive tool for searching for appropriate materials. [1] W. Chen, M. Sigrist, J. Sinova, and D. Manske, Phys. Rev. Lett. 115, 217203 (2015). [2] S. Ok, W. Chen, M. Sigrist, and D. Manske, arXiv:1607.03409.

MA 64.29 Fri 9:30 P2-EG

Spin Hall magnetoresistance in a non-collinear ferrimagnet — Bo-Wen Dong[1,2,3], •Andrew Ross[1], Joel Cramer[1,2], Kathrin Ganzhorn[4,5], Huai-Yang Yuan[1], Er-Jia Guo[1,6], Sebastian T. B. Goennenwein[4,5], and Mathias Kläui[1,2] — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), Germany — [3]University of Science and Technology Beijing, China — [4]Bayerische Akademie der Wissenschaften, Germany — [5]Technische Universität München, Germany — [6]Oak Ridge National Laboratory, TN, USA

The spin Hall magnetoresistance (SMR) of a gadolinium iron garnet (GdIG)/platinum (Pt) heterostructure was investigated by angular dependent measurements around the compensation temperature of the ferrimagnet, GdIG. Around this temperature, GdIG exhibits a non-collinear magnetic structure, which displays an atypical SMR signal[1]. Far from this temperature, the GdIG is collinear and the resistance displays the usual $\sin^2\gamma$ dependence[2]. However, as the temperature is swept around the compensation temperature, the angular dependence becomes more complex with the development of additional peaks that grow until the SMR signal inverts before being suppressed, returning to the typical signal of a collinear ferrimagnet. The number and strength of the peaks appearing in the signal depend on both the temperature and the strength of the applied field. Our results demonstrate the limitations of the current SMR formalism, developed for collinear magnetic structures [1][2]. [1] Ganzhorn et al, Phys. Rev. B 94, 094401(2016), [2] Nakayama et al, Phys. Rev. Lett 110, 206601(2013)

MA 64.30 Fri 9:30 P2-EG

Relational expression between spin polarization ratio and anisotropic magnetoresistance ratio for nearly half-metallic ferromagnets — •Satoshi Kokado[1], Yuya Sakuraba[2], and Masakiyo Tsunoda[3] — [1]Shizuoka University, Hamamatsu, Japan — [2]National Institute for Materials Science, Tsukuba, Japan — [3]Tohoku University, Sendai, Japan

A current-perpendicular-to-plane giant magnetoresistance effect for ferromagnet/metal/ferromagnet junctions increases with increasing the spin polarization ratio of resistivity, P_ρ, in the ferromagnet. A simple method to estimate P_ρ, however, has scarcely been proposed. In this study, we derive a simple relational expression between P_ρ and the anisotropic magnetoresistance ratio $\Delta\rho/\rho$, and that between the spin polarization ratio of the density of states at the Fermi energy, $P_{\rm DOS}$, and $\Delta\rho/\rho$ for nearly half-metallic ferromagnets [1]. We here use the two-current model for a system consisting of a spin-polarized conduction state and localized d states with spin–orbit interaction [1-3]. We find that P_ρ and $P_{\rm DOS}$ increase with increasing $\Delta\rho/\rho$ from 0 to a maximum value. In addition, we investigate P_ρ and $P_{\rm DOS}$ for a $Co_2FeGa_{0.5}Ge_{0.5}$ Heusler alloy [4] by substituting its experimentally observed $\Delta\rho/\rho$ into the respective expressions.

[1] S. Kokado *et al.*, Jpn. J. Appl. Phys. **55**, 108004 (2016).
[2] S. Kokado *et al.*, J. Phys. Soc. Jpn. **81**, 024705 (2012).
[3] S. Kokado *et al.*, Adv. Mater. Res. **750-752**, 978 (2013).
[4] Y. Sakuraba *et al.*, Appl. Phys. Lett. **104**, 172407 (2014).

MA 64.31 Fri 9:30 P2-EG

Thin films of the room temperature antiferromagnet CuMnAs deposited by magnetron sputtering — •Tristan Matalla-Wagner, Dario Linsen, Jan-Michael Schmalhorst, Timo Kuschel, Markus Meinert, and Günter Reiss — Center for Spinelectronic Materials and Devices, Bielefeld University, Germany

Antiferromagnets (AFM) are barely affected by external magnetic fields and their magnetic properties are notoriously difficult to manipulate and detect. However, it was recently demonstrated that the metastable tetragonal phase of CuMnAs fulfills the symmetry requirements for an intrinsic spin-orbit torque, that allows magnetization switching with current pulses of moderate density and magnetization read-out by the planar Hall effect [1]. Therefore, this material holds promise to manufacture novel antiferromagnetic memory devices that are extraordinarily robust against external influences [2]. Tetragonal CuMnAs is specifically promising due to its Néel temperature being well above room-temperature [3]. It was demonstrated that high quality CuMnAs films can be grown in the tetragonal phase on GaAs and GaP substrates by molecular beam epitaxy [4]. Here, we present the results of our recent progress to deposit CuMnAs films on GaAs (001) substrates by magnetron sputtering and discuss structural, magnetic, and electrical properties of the films.

[1] P. Wadley *et al.*, Science **351** 587 (2016)
[2] T. Jungwirth *et al.*, Nat. Nanotechn. **11** 231 (2016)
[3] F. Máca *et al.*, J. Magn. Magn. Mater. **324** 1606 (2012)
[4] P. Wadley *et al.*, Nat. Commun. **4** 2322 (2013)

MA 64.32 Fri 9:30 P2-EG

Spin Hall magnetorestiance in Pt/$La_{0.875}Sr_{0.125}MnO_3$ heterostructures — •Sarah Gelder[1,2], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

The interconversion of spin and charge currents via the (inverse) spin Hall effect in normal metal (NM)/ferromagnetic insulator (FMI) bilayers results in the spin Hall magnetoresistance (SMR). In the past years, the SMR was extensively investigated in the prototype bilayer system platinum/yttrium iron garnet (Pt/YIG). Here, we use $La_{1-x}Sr_xMnO_3$ (LSMO) with low doping level x=0.125 as the ferromagnetic insulator, exhibiting a T_c of 180K and phase transitions at 270K and at 150K. This material allows further insight into the dependence of the SMR on the magnetic properties of the ferromagnetic material. We have fabricated Pt/LSMO bilayers on (100)-oriented $SrTiO_3$ substrates by pulsed laser deposition of LSMO and subsequent electron beam evaporation of Pt. The high crystalline quallity as well as the magnetic properties of our LSMO thin films are confirmed by X-ray diffraction and SQUID magnetometry measurements. We performed angle-dependent magnetoresistance (ADMR) measurements, providing the SMR amplitude as a function of temperature and magnetic field strength . We correlate the experimental findings with the magnetic properties of LSMO. This work is supported by the DFG via SPP 1538.

MA 64.33 Fri 9:30 P2-EG

Impact of aging process on the magnetotransport properties of Co/Pd layered structures — •Afsaneh Farhadi Ghalati[1], André Philippi-Kobs[1,2], Dieter Lott[3], Jonathan Jacobsohn[1], Gerrit Winkler[1], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany — [2]Coherent X-ray Scattering (FS-CXS), Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany — [3]Helmholtz-Zentrum Geesthacht, Zentrum für Material- und Küstenforschung GmbH, Max-Planck-str. 1, 21502 Geesthacht, Germany

The stability of magnetic thin films is an important issue for their application. In contrast to Co/Pt sandwiches, Co/Pd shows strong changes in the magnetotransport properties over time. Here, over a time span of 600 days, we have investigated the impact of aging on the various magnetoresistance effects present in longitudinal and transverse resistivity of Pd/Co/Pd sandwiches under ambient conditions. Two Co/Pd samples with Co thicknesses of 2 & 7 nm have been prepared via sputtering techniques. The results show strong variations of the MR properties in the first three months followed by a slower change to equilibrium values. However, there are significant differences between both samples reflecting different behavior of Co/Pd systems governed by bulk-like or interface contributions. X-ray reflectivity studies accompanying the MR investigations confirm the aging of the samples and particularly reveal a gradual intermixing of Co and Pd at the interfaces that happens on a time span of several months.

MA 64.34 Fri 9:30 P2-EG

Gilbert damping of magnetostatic modes in yttrium iron garnet spheres — •Stefan Klingler[1,2], Hannes Maier-Flaig[1,2], Carsten Dubs[3], Oleskii Surzhenko[3], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], Sebastian T.B. Goennenwein[1,5,6], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]INNOVENT e.V. Technologieentwicklung, Jena, Germany — [4]Nanosystems Initiative Munich, München, Germany — [5]Institut für Festköperphysik, TU Dresden, Dresden, Germany — [6]Center for Transport and Devices of Emergent Materials, TU Dresden, Germany

The ferrimagnetic insulator yttrium iron garnet (YIG) has numerous applications in fundamental research due to its low intrinsic Gilbert damping. Recently, strong coupling between magnon modes in YIG spheres and photonic modes in microwave resonators gained interest for quantum information conversion. To this end, the detailed knowledge of damping in the magnetic system plays a crucial role. Here, we investigate the magnetostatic mode (MSM) spectrum of a $300\,\mu$m diameter YIG sphere using broadband ferromagnetic resonance. The measured data allows to separate Gilbert damping and inhomogeneous line broadening of the MSMs. One and the same Gilbert damping parameter $\alpha = 2.7(5) \times 10^{-5}$ is found for all MSMs. However, the inhomogeneous line broadening differs between the investigated MSMs, which is explained by two-magnon scattering processes of the MSMs into the spin-wave manifold, mediated by surface and volume defects.

MA 64.35 Fri 9:30 P2-EG

Spin Current Detection via Interface Paramagnetic Resonance — Thomas Marzi[1], •Ralf Meckenstock[1], Sabrina Masur[2], and Michael Farle[1,3] — [1]Faculty of Physics, AG Farle, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Cavendish Laboratory, Department of Physics, Cambridge CB3 0HE, United Kingdom — [3]Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russian Federation

We managed to use electron spin resonance active centers at ferromagnetic or metallic interfaces as a probe for measuring contact free pure spin currents for small spintronic devices and the temperature change at the surface of nano particles at human tissue relevant temperatures. Oleic acid is chemisorbed on surfaces of interest consisting of magnetic materials in our case Fe or Fe_xO_y or metallic or oxidized materials like Ag or TiO_2, yielding paramagnetic centers detected by electron spin resonance (ESR). To show the potential of the method epitaxially grown Fe films and single crystalline nanoparticles of diameters less than 40nm were investigated. While the paramagnetic centers are at resonance, they react extremely sensitive on local changes of magnetic, crystalline or thermal parameters of their nearest neighbors. Being at the resonance of the ESR centers, we managed to switch on and off pure spin currents emitted by the microwave excited precessional motion of the magnetic moments from a ferromagnet by adjusting the angle between an external magnetic field and the sample plane. The flow of spin momentum is reflected in the microwave power dependent absorption characteristics of the ESR. (supported by DFG SPP1538)

MA 64.36 Fri 9:30 P2-EG

Auto-oscillations in YIG/Pt microstructures driven by the spin Hall effect and the spin Seebeck effect — •Michael Schneider[1], Viktor Lauer[1], Thomas Meyer[1], Phillip Pirro[1], Thomas Brächer[1], Björn Heinz[1], Bert Lägel[1], Carsten Dubs[2], Caroline A. Ross[3], Mehmet C. Onbasli[3], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung, 07745 Jena, Germany — [3]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

We report on the experimental results of the dynamics of spin Hall effect (SHE) and spin Seebeck effect (SSE) induced magnetization auto-oscillations in YIG/Pt microstructures. The investigated structures differ with respect to their geometry and fabrication methods. DC current pulses result in a generation of a spin current due to the SHE and in a Joule heating of the Pt layer. The heating leads to the formation of a thermal gradient and to the formation of a SSE spin current, which exerts an anti-damping torque and causes magnetization precession. Time-resolved Brillouin light scattering microscopy is used to investigate the magnetization precession as a function of time and spatial position. The interplay between different excited spin-wave modes is adressed. This research has been supported by: EU-FET Grant InSpin 612759, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1, and SE 1771/4-2 within SPP 1538).

MA 64.37 Fri 9:30 P2-EG

Magnetic linear dichroism of 3d metal thin films — •Torsten Veltum[1], Tobias Löffler[1], Mathias Gehlmann[2], Lukasz Plucinski[2], Claus Michael Schneider[2], Stephan Borek[3], Jan Minár[3], Jürgen Braun[3], Hubert Ebert[3], and Mathias Getzlaff[1] — [1]Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52428 Jülich — [3]Dep. Chemie und Biochemie, Universität München, Butenandstr. 5-13, 81377 München

Magnetic linear dichroism in the angular distribution of photoelectrons (MLDAD) is a technique that allows the study of both the electronic band structure and the magnetic properties of thin films and single crystals. We study epitaxially grown Co(0001) thin films on a W(110) surface.

In this study linearly polarized synchrotron radiation (Beamline 5, DELTA Dortmund) in the VUV regime is used to gain angle-resolved photoelectron spectroscopy data. The theoretical calculations make use of dynamical mean-field theory (DMFT), including a complete calculation within the one-step model (1SM) of photoemission, using the local spin-density approximation (LSDA).

We compare the theoretical and experimental data to best fit peak positions and the asymmetry of the spectra as a function of excitation energy, using different values for the averaged on-site Coulomb interaction U.

MA 64.38 Fri 9:30 P2-EG

Magnon-polariton experiments at milliKelvin temperatures — •Marco Pfirrmann[1], Julius Krause[1], Yannick Schön[1], Isabella Boventer[2], Andre Schneider[1], Alexey V. Ustinov[1], and Martin Weides[1,2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology — [2]Institute of Physics, Johannes Gutenberg University Mainz

While magnon dynamics in ferromagnetic materials has been studied for decades with respect to ferromagnetic resonances, Bose-Einstein condensation, and spintronics, there has been recent progress towards studying collective spin excitations in the quantum regime. Strongly coupled quantum hybrid systems of microwave photons and magnons (magnon-polaritons) mediate the interaction between well-controlled superconducting quantum-circuits and magnetic materials.

An important criterion for possible applications in quantum information processing is the magnon resonance linewidth, the information on the lifetime of a quantum memory. We investigate a strongly coupled hybrid system consisting of a YIG sphere and a 3D microwave cavity. We focus on temperature dependent magnon-polariton properties obtained by spectroscopic measurements at temperatures between 25 and 1600 mK. The coupling and the internal linewidths of resonator and magnon resonances are obtained by fitting the full complex scattering parameter using Input-Output-formalism adapted from quantum optics.

MA 64.39 Fri 9:30 P2-EG

Skyrmion lattice dynamics — •Lukas Heinen and Achim Rosch — Institute for Theoretical Physics, University of Cologne, Germany

Chiral magnets host a rich magnetic phase diagram, of which the skyrmion lattice phase is particularly interesting. Skyrmions carry an integer winding number and hence are topologically protected. In addition, making them a promising candidate for future spintronic devices, they are easy to manipulate. Early on it was demonstrated that even the small temperature gradient induced by a Lorentz Transmission Electron Microscope is enough to induce a rotation in a skyrmion lattice. We examine the dynamics of such a rotating skyrmion lattice, by combining micromagnetic simulations with point particle simulations. Of particular interest is the role of defects in the skyrmion lattice.

MA 64.40 Fri 9:30 P2-EG

Demagnetisation energy and magnetisation variation effects on the isolated skyrmion dynamics — •Marijan Beg[1], David I. Cortés-Ortuño[1], Weiwei Wang[1,2], Rebecca Carey[1], Mark Vousden[1], Ondrej Hovorka[1], and Hans Fangohr[1] — [1]Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, United Kingdom — [2]Department of Physics, Ningbo University, Ningbo, 315211, China

Usually for simplicity, in the simulations of skyrmionic states in helimagnetic samples, the demagnetisation energy is neglected and/or thin film samples are modelled using two-dimensional meshes. In this work, we investigate how these two assumptions affect the dynamics of an isolated skyrmion state in a 150 nm diameter FeGe disk. Firstly, we simulate the isolated skyrmion state dynamics using a full three-dimensional model. Secondly, we repeat the simulation under the same conditions, but this time we set the demagnetisation energy artificially to zero. Finally, we use a 2D mesh to model a thin film sample. We compare the power spectral densities and observe that although the magnetisation dynamics associated to the identified eigenmodes do not change significantly, their frequencies change substantially. We conclude that neglecting the demagnetisation energy contribution or modelling 3D samples using two-dimensional meshes in skyrmionic state dynamics simulations is not always justified. This work was supported by the EPSRC's EP/G03690X/1 and EP/N032128/1 grants and the Horizon 2020 European Research Infrastructure project (676541).

MA 64.41 Fri 9:30 P2-EG

Simulation of magnetic fibers and textile coatings — •Tomasz Blachowicz[1] and Andrea Ehrmann[2] — [1]Silesian University of Technology, Gliwice, Poland — [2]Bielefeld University of Applied Sciences, Bielefeld, Germany

While simulations of mechanical or conductive properties of textile fibers and textile coatings are being used for a long time, their magnetic properties still lack theoretical descriptions. Due to the broad variety of possible applications of magnetic textiles, such as magnetic coils and sensors, magnetic filters, or invisible magnetic water-marks, simulations would nevertheless be supportive in further developments in this area of smart textiles.

The poster presents different possibilities of micromagnetically modeling magnetic fibers and coatings on fibers and complete textile fabrics [1]. It shows the influence of fiber and coating dimensions on the simulated magnetic properties, depending on the magnetic material and the fiber composition, including interactions between neighboring coated fibers [2]. The shape anisotropy is shown to dominate the magnetic properties of both magnetic fibers and coatings; the effect of this result on possibilities of adjusting the magnetic properties of textile fabrics to a desired application is depicted.

[1] A. Ehrmann, T. Blachowicz: Micromagnetic simulation of fibers and coatings on textiles, Journal of The Institution of Engineers (India): Series E 96, 145-150

[2] T. Blachowicz, A. Ehrmann: Simulation of magnetic coatings on textile fibers, Journal of Physics: Conference Series 738, 012057 (2016)

MA 64.42 Fri 9:30 P2-EG

Magnetically Patterned Rolled-Up Exchange Bias Tubes: A Paternoster for Superparamagnetic Beads — •Timo Ueltzhöffer[1], Robert Streubel[2], Iris Koch[1], Dennis Holzinger[1], Denys Makarov[2], Oliver G. Schmidt[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel (Germany) — [2]Institute for Integrative Nanosciences, Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Helmholtzstraße 20, 01069 Dresden (Germany)

A deterministic transport system for superparamagnetic microbeads through magnetically designed tubular microchannels was realized. The beads are transported in a stepwise manner exhibiting paternoster-like trajectories as they are moved through the tube and back on top of it. The transport could be controlled by a series of weak magnetic field pulses and takes advantage of the magnetic stray field that emerge from the patterned microtubes. In order to fabricate such microtubes, strain engineered layers were covered by an exchange bias system, patterned by light ion bombardment on parallel stripes and subsequently rolled up. This approach impacts several fields of 3D applications in biotechnology, including particle transport related phenomena in lab-on-a-chip and lab-in-a-tube devices.

[1] Ueltzhöffer, T. et al. Magnetically Patterned Rolled-Up Exchange Bias Tubes: A Paternoster for Superparamagnetic Beads. ACS Nano 10, 8491-8498 (2016).

MA 64.43 Fri 9:30 P2-EG

Skyrmions at the edge: Confinement effects in Fe/Ir(111) — •Andre Kubetzka, Julian Hagemeister, Davide Iaia, Elena Y. Vedmedenko, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

The fcc Fe atomic layer on Ir(111) hosts a unique magnetic skyrmion lattice with square symmetry and a period of only 1 nm. The lattice is induced by the 4-spin interaction already in zero magnetic field [1]. Here we employ spin-polarized STM at $T = 8\,\mathrm{K}$ and Monte Carlo simulations to investigate the effect of free and ferromagnetic edges onto the nanoskyrmion lattice [2]. In triangular islands the coupling to the edges and the mismatching symmetries lead to multidomain states. In the MC simulations, despite the lower energy of a single-domain state, multidomain states arise by the combined effect of entropy and an intrinsic domain wall pinning, which results from the skyrmionic character of the spin texture.

[1] S. Heinze *et al.*, Nat. Phys. **7**, 713 (2011).

[2] J. Hagemeister *et al.*, Phys. Rev. Lett. **117**, 207202 (2016).

MA 64.44 Fri 9:30 P2-EG

Bottom-up fabrication of periodic magnetic nanostructures based on ion-induced spontaneous surface nanopatterning — •Denise Erb[1], Xin Ou[1,2], Kai Schlage[3], Kilian Lenz[1], Ralf Röhlsberger[3], Jürgen Lindner[1], Stefan Facsko[1], Manfred Helm[1,4], and Jürgen Fassbender[1,4] — [1]HZDR, Dresden, Germany — [2]SIMIT, Shanghai, China — [3]DESY, Hamburg, Germany — [4]TU Dresden, Dresden, Germany

Large-area nanopatterning is a key requirement in diverse applications ranging from photovoltaics to computing and biomolecule detection. We present a simple and scalable bottom-up nanopatterning approach based on ion irradiation of semiconductor surfaces and well-established thin film deposition techniques: On crystalline semiconductor substrates, nanoscale surface patterns with well-defined lateral periodicity form via the mechanism of reverse epitaxy, i.e. the non-equilibrium self-assembly of vacancies and ad-atoms under ion irradiation [1]. The nanopatterned surfaces can for instance be employed as substrates for MBE under grazing incidence, producing periodic metal nanostructures by geometrical shading. They can also be the basis for metal nanostructure growth in a variety of pattern morphologies by hierarchical self-assembly [2]. In this contribution, we outline the reverse epitaxy mechanism and present examples of periodic magnetic nanostructures based on the resulting surface patterns. We hope to stimulate discussion of further applications in magnetism by emphasizing the simplicity and versatility of this bottom-up approach. [1] Ou et al., Nanoscale 7 (2015); [2] Erb et al., Science Advances 1 (2015)

MA 64.45 Fri 9:30 P2-EG

non-collinear magnetism of mn nanostructures adsorbed on nobel metal (111) surfaces — •Ramon Cardias[1,2], Manoel Bezerra-Neto[1], Marcelo Ribeiro[1], Anders Bergman[2], Angela Klautau[1], and Olle Eriksson[2] — [1]Universidade Federal do Pará — [2]Uppsala University

The magnetic properties of Mn nanostructures adsorbed on Ag(111) and Au(111) surfaces have been investigated by means of first principles calculations allowing for noncollinear coupling between atomic spins. Our calculations of interatomic exchange interactions reveal the strong exchange interactions between Mn atoms on Ag(111), which rules the magnetic ordering for Mn clusters on this substrate. For Mn nanostructures on Au(111), the effect of spin-orbit coupling leads to the possibility of realizing complex noncollinear magnetic structures such as ring-like antiferromagnetic one, and other exotic three-dimensional magnetic structures. The effect of the structural relaxation is also investigated, showing bond-substrate distance dependent for the exchange interactions. In the end, we reveal the Dzyaloshinskii-Moriya interaction for the Mn monolayer on both surface and for some nanoclusters, studying the influence of this interaction.

MA 64.46 Fri 9:30 P2-EG

Room temperature magnetic hardening of FeCo nanowire arrays — •Fangzhou Wang[1], Ruslan Salikhov[1], Marina Spasova[1], Sara Liébana-Viñas[1], Christina Bran[2], Yu-Shen Chen[2,3], Manuel Vázquez[2], Michael Farle[1,4], and Ulf Wiedwald[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Germany — [2]Institute of Materials Science of Madrid, CSIC, Madrid, Spain — [3]Department of Chemical Engineering and Materials Science, Yuan-Ze University, Chung-Li, Taiwan — [4]Center for Functionalized Magnetic Materials (FunMagMa), Immanuel Kant Baltic Federal University, Kaliningrad, Russia

Exploiting the shape anisotropy in combination with the magnetocrystalline anisotropy of 3d-metal nanowires (NW) yields a large energy product, i.e. high remanent magnetization (M_R) and large coercive field (H_C). It has been shown recently that M_R and H_C can be significantly enhanced at low temperatures by oxidizing FeCo NW tips [1]. Here, we demonstrate the magnetic hardening of FeCo NWs by interfacing their tips with AFM $Fe_{50}Mn_{50}$ layers at 300 K. FM NWs with diameter of 40 nm and length of 16 μm were grown in Anodic Aluminum Oxide (AAO) nanopores. Both tips of NWs were opened by partial chemical etching of the AAO membrane and, subsequently, $Fe_{50}Mn_{50}$ was deposited by rf-sputtering forming an AFM/FM/AFM sandwich structure. As a result, the absolute enhancement of H_C is 50 mT, while the relative increase is 50% and 24% for H_C and M_R at 300 K. [1] S. Liébana-Viñas et al., Nanotechnology 26, 415704 (2015).

MA 64.47 Fri 9:30 P2-EG

Fabrication and self-organization studies of polymer nanoparticles functionalized by exchange bias layer system via nanoimprint lithography — •Jendrik Gördes[1], Timo Ueltzhöffer[1], Sabrina Reuter[2], Uh-Myong Ha[2], Arno Ehresmann[1], and Hartmut Hillmer[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]Institute of Nanostructure Technologies and Analytics (INA) and Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Cuboid polymer nanoparticles have been fabricated by substrate conformal imprint lithography (SCIL [1]). The particles were functionalized by covering them with an exchange bias layer system. They were geometrically characterized by scanning electron microscopy and magnetically by Kerr magnetometry. The functionalization by an exchange bias layer system introduces a defined magnetic anisotropy along a geometric axis of the brick-shaped particles. Agglomeration characteristics of these particles were investigated indicating that magnetic functionalization can control the self-organization of macrostructures out of designed imprinted particles.
[1] V. R. Kolli, C. Woidt and H. Hillmer, Advanced Materials Research. Vol. 1119, pp. 179-183 (2015) Trans Tech Publications

MA 64.48 Fri 9:30 P2-EG

Correlation in (un-)frustrated artificial spin ice — •Jochen Wagner[1], Stefan Freercks[1], Ralph Buss[1], Kai Bagschik[1], Robert Frömter[1], Matthias Riepp[2], André Philippi-Kobs[2], Magnus H. Berntsen[3], Leonard Müller[2], Gerhard Grübel[2], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Uni Hamburg, Germany — [2]DESY, Hamburg, Germany — [3]KTH Royal Institute of Technology, Stockholm, Sweden

X-ray holographic microscopy (XHM) has become a competitive technique to investigate magnetic samples with sub-20-nm spatial resolution exploiting x-ray magnetic circular dichroism [1]. With this technique, we imaged simple-cubic (unfrustrated) and kagome (frustrated) artificial spin ice (ASI) made up of nanodots with perpendicular magnetization. The nanodots are structured by e-beam lithography from $(Co_{0-2nm}/Pt_{1.4nm})_{10}$ multilayer films prepared by dc magnetron sputtering and ion assisted sputtering on Si_3N_4 membranes. The dots have diameters of 90 nm and 110, 130 or 160 nm next-neighbor distance. The simple-cubic ASIs favor an alternating, checkerboard-like state for the 110 nm distances, indicating a short-range order due to magnetostatic interaction. For larger distances no order could be observed and the ASI show random distribution. For the kagome ASI a similar behavior is observed. Due to magnetostatic interaction, they strongly favor a two-up one-down or vice versa state, following the ice rule. This correlation was again not observed at larger distances of 130 and 160 nm.
[1] D. Stickler, et al., Appl. Phys. Lett. 96, 042501 (2010).

MA 64.49 Fri 9:30 P2-EG

Micro-Hall magnetometry on macro-, micro- and nanoscale samples — •Mohanad K I Mamoori, Merlin Pohlit, Jonathan Pieper, and Jens Müller — Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt am Main , Germany

Micro-Hall sensors are versatile tools for studying the local magnetic induction of macro-, micro- and nano-scale samples in a wide range of temperatures and magnetic fields. Along with measurements of thermal dynamics in artificial spin ice systems [1], we recently have applied First Order Reversal Curves (FORC) – a powerful technique to characterize the hysteresis loop of magnetic materials in detail and to study various intrinsic effects as, e.g., different grain sizes, dipolar interactions, and phase mixtures – to individual and dipolar-coupled arrays of magnetic nanostructures using micro-Hall sensors [2].
In this presentation, we review the different areas of the sensor applications discussing both static and dynamic measurments, and focus on the investigation of local effects in macroscopic samples, ranging from the formation of nano-scale magnetic clusters in colossal magnetoresistance materials to avalanche dynamics in metallic glasses.
[1] Pohlit et al., J. Appl. Phys. 120, 142103 (2016).
[2] Pohlit et al., Rev. Sci. Instrum. 87, 113907 (2016).

MA 64.50 Fri 9:30 P2-EG

Magnetic properties of nanostructured Tb-Fe alloy thin films — •Sri Sai Phani Kanth Arekapudi[1,3], Olav Hellwig[1,2], and Manfred Albrecht[3] — [1]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany — [2]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [3]Institute of Physics, University of Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Nanostructured ferrimagnetic Tb-Fe alloy thin films were prepared on pre-patterned substrates as underlying template, consisting of nanodot arrays with a dot diameter of 30 nm and a period of 60 nm. Two distinct magnetic configuration are possible, one where the magnetic material on the nanodot and in the trenches is decoupled from each other for film thicknesses below the nanodot height, and the other where full exchange coupling between magnetic material on the dots and in the trenches is effective for magnetic films thicker than the nanodot height. Regardless, of the magnetic configuration the reversal of the magnetic material on top of the nanodots is found to be nucleation dominated, while the magnetic material in the trenches reverses via domain wall propagation, as confirmed by in-field magnetic force microscopy. The distinct behavior in this system is attributed to the reduced exchange stiffness followed by relatively narrow domain walls (approx. 3-4 nm) present in these rare earth - transition metal alloys [1]. A systematic study of magnetic properties on nanostructured Tb-Fe alloy films as a function of composition and film thickness will be presented.

MA 64.51 Fri 9:30 P2-EG

Characterization of micromachined Si cantilever giant magnetoimpedance (GMI) device for hybrid strain and magnetic field sensing in the high frequency regime — •Gregor Büttel and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

Magnetoresistive sensors on flexible substrates and cantilevers gain more attention for high sensitivity strain gauges and wearable electronics [1]. We have developed a fabrication process relying on common lithography and Si micromachining methods to obtain a coplanar waveguide-based GMI device located across the bending edge between a Si cantilever and its support to apply local stress. The device is 50 Ω on-chip terminated with NiCr film resistors to allow for network analyzer measurements in the GHz regime while bending the cantilever with a nanomanipulator. The signal line involving a Permalloy multilayer system can be integrated onto a Si Cantilever. Magneto-optical Kerr microscopy and micromagnetic simulations complement and support the impedance measurements revealing a magnetic domain rotation under strain. We discuss appropriate ac current frequencies for a high GMI ratio under applied stress/field and possible material and layer systems to further enhance the sensors performance. [1] Tavassolizadeh, A. et al. APL 102.15 (2013): 153104.

MA 64.52 Fri 9:30 P2-EG

Combined Optical and Magnetical Trapping of Magnetic Microbeads — •Florian Ostermaier[1], Benjamin Riedmüller[1], Tobias Neckernuss[2], Othmar Marti[2], and Ulrich Herr[1] — [1]Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland — [2]Institut für Experimentelle Physik, Universität Ulm, Ulm, Deutschland

Optical tweezers have been established as a powerful tool for manipulation of particles in the range from nanometers to micrometers with subnanometer accuracy. On the other hand, magnetic nanoparticles are widely used for bonding and detecting biological analytes in Lab-on-Chip systems. Magnetic nanoparticles can be effectively manipulated by magnetic field gradients. In previous works, we have developed a novel method for stable positioning of superparamagnetic nanoparticles on the micro-scale using a combination of the field gradient produced by tapered conductor lines and a superimposed homogeneous magnetic field. The combination of both methods opens up new perspectives for applications of nanoparticles in absorbing media. We present first experiments aiming at integration of a magnetic microtrap on a transparent substrate into an existing optical tweezer setup. Using commercially available microbeads (Dynabeads MyOne Streptavidin T1, diameter 1 μm) it is observed that numerous influences affect the stability of the particles in the micro-trap under standard operating conditions in the optical tweezer setup. Possible origins of the instabilities are discussed.

MA 64.53 Fri 9:30 P2-EG

Characterization of single YIG microstructures using Brillouin light scattering microscopy — •Björn Heinz[1], Thomas Meyer[1], Philipp Pirro[1], Thomas Brächer[1,3], Carsten Dubs[2], Oleksii Surzhenko[2], Burkard Hillebrands[1], and Andrii Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung Jena, 07745 Jena, Germany — [3]Université Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, 38054 Grenoble, France

We investigate the magnetization dynamics in single YIG microstructures. The structures are patterned from a 98 nm thick LPE-grown YIG film and have a square shape with lateral sizes down to 800 nm. By exciting the magnetization dynamics with a microwave field and performing Brillouin light scattering microscopy measurements, different lateral standing modes are observed. Comparing the measurements to micromagnetic simulations, the spin wave modes are identified. Furthermore, a magnetic field dependent determination of the resonance frequency and the linewidth of the fundamental mode is performed. For the subsequent determination of the saturation magnetization and the Gilbert damping parameter of individual microstructures, quantization effects need to be taken into account. The results indicate a small decrease of the saturation magnetization and an increased Gilbert damping which needs to be considered for future investigation of YIG microstructures. This research has been supported by ERC Starting Grant 678309 MagnonCircuit and DFG Grant DU 1427/2-1.

MA 64.54 Fri 9:30 P2-EG

Spin pumping near the magnetic phase transition in ultrathin Fe/Pd bilayers — •Jochen Greser, Sascha Keller, Matthias R. Schweizer, Burkard Hillebrands, and Evangelos Th. Papaioannou — Fachbereich Physik, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany

Spin pumping (SP) is a powerful tool to generate pure spin currents which are a key ingredient in spintronic devices. The electrical detection of a pure spin current can be accomplished by the inverse spin Hall effect (ISHE) using metals with strong spin-orbit interaction, such as Pd. In this work SP close to the ferromagnetic (FM)/paramagnetic (PM) phase transition is investigated. On the contrary to the studies so far where the phase transition has been created in samples composed of a PM layer to FM/Pt or YIG/Pt bilayers, here only one FM layer is used in order to drive the phase transition. This can be achieved by using δ-doped Fe/Pd bilayers which have the advantage of a controllable Curie temperature T_C. A high ISHE voltage has been observed for extremely thin Fe layers around the phase transition.

MA 64.55 Fri 9:30 P2-EG

Spin waves in CoFeB thin films dominated by Dzyaloshinskii-Moriya interaction — •Tobias Fischer[1,2], Frank Heussner[1], Mathias Kläui[2,3], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Straße 56, 67663 Kaiserslautern — [2]MAINZ Graduate School of Excellence, Staudingerweg 9, 55128 Mainz — [3]Johannes Gutenberg-Universität, Institut für Physik, Staudingerweg 7, 55128 Mainz

As predicted by Dzyaloshinskii and Moriya, in low-symmetry systems the exchange interaction exhibits an antisymmetric contribution. This effect also occurs in ultra-thin films where both the broken inversion symmetry and the selection of a capping material with a large spin-orbit interaction can lead to a strong interfacial Dzyaloshinskii-Moriya interaction (DMI) [1]. In consequence, an additional term which is linear in the spin-wave wave vector enters the dispersion relation of spin waves propagating perpendicular to the static magnetization.

We present results of the investigation of the spin-wave spectrum in ultra-thin CoFeB (0.6 nm) films covered with Pt and W, respectively, employing wave-vector resolved Brillouin light scattering spectroscopy. We find a strong influence of the DMI which leads to a collinear group velocity for both positive and negative wave vectors raising interesting questions on the nature of scattering processes in such systems.

Financial support within the SFB/TRR 173 *Spin+X* is gratefully acknowledged.

[1] A. A. Stashkevich *et al.*, Phys. Rev. B **91**, 214409 (2015).

MA 64.56 Fri 9:30 P2-EG

Spin-dependent magnetization dynamics in the Tb(0001) surface state — •Sang-Eun Lee, Beatrice Andres, and Martin Weinelt — Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Ultrafast laser-induced demagnetization of heavy lanthanides differs from that of transition metals, since its dynamics is described by more than one exponential time constant. Employing spin-, time- and energy-resolved photoemission spectroscopy we have studied the case of Gd(0001) [1]. With the same tool, in this study, we investigate the demagnetization of Tb when it is excited with ultrafast laser pulses. From the broadening of the Fermi function we can extract the spin-dependent temporal evolution of the electron temperature. Comparing this to the changing spin-polarization and binding energy of the Tb(0001) surface state, we are able to distinguish between different processes driving the demagnetization, such as Eliott-Yafet scattering or spin transport. To show a distinctive behavior of laser-induced demagnetization, we compare the spin-polarization and binding energy change of this process to those of the equilibrium phase transition. We further compare the magnetization dynamics of Tb and Gd.

[1] B. Andres *et. al.*, *Phys. Rev. Lett. 115* **20**, 207404 (2015).

MA 64.57 Fri 9:30 P2-EG

Photon energy dependent fs-demagnetization dynamics of thin Ni films — •Jonas Hoefer, Sebastian Weber, Ute Bierbrauer, David Schummer, Moritz Barkowski, Benjamin Stadtmüller, Bärbel Rethfeld, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

After the first observation of the ultrafast demagnetization process of ferromagnetic thin films on the femtosecond timescale, 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.

In this context, almost all experimental studies so far employed fs light pulses of 1.55eV to trigger the fs-demagnetization dynamics.

Hence, the role of the photon energy of the exciting light pulse has not been investigates 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 3.10eV. As prototypical system, we first 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 quenching of magnetization, will be compared to simulations describing the non-equilibrium dynamics of the spin-carrying excited electrons.

MA 64.58 Fri 9:30 P2-EG

DPC measurements of local hysteresis loops on annealed cobalt thin films — •Felix Schwarzhuber, Thomas Beer, and Josef Zweck — Institute for Experimental and Applied Physics, University of Regensburg, Germany

Differential Phase Contrast Microscopy (DPC) in a Scanning Transmission Electron Microscope allows us to obtain detailed information about microscopic distributions of the magnetic induction within a specimen.

In this work we performed DPC tilting series on 50 nm thick annealed cobalt thin films to gather information about their magnetic properties. By tilting the specimen relative to the magnetic field of the objective lens we change the effective in-plane field acting on our samples, leading to a change of the in-plane induction distribution in our cobalt thin films. This change can be imaged in detail with our DPC setup. As we investigate a small area of the specimen (few microns square) we are able to measure local magnetic hysteresis effects. The obtained hysteresis loops and DPC images let us clearly distinguish whether the remagnetization processes included a vortex core or not. In addition, we are also able to observe pinning of magnetic features on larger cobalt crystallites.

MA 64.59 Fri 9:30 P2-EG

Magnon Supercurrents by Thermal Gradients — •Alexander J.E. Kreil[1], Dmytro A. Bozhko[1,2], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

Currently, supercurrents in a room-temperature magnon Bose-Einstein condensate (BEC) have been reported [1]. The condensate created by parametric microwave pumping in a tangentially magnetized yttrium-iron-garnet (YIG) film is studied by means of the time-resolved Brillouin light scattering (BLS) spectroscopy technique. The heating in the focus of a probing laser beam leads to the temperature-induced spatial variation in the saturation magnetization and, thus, to the variation in the local magnon frequencies across the heated film area. Because the magnon condensate is coherent across the entire heated area, a spatially varying phase shift is imprinted into its wavefunction. This spatial phase gradient propels a magnon supercurrent flowing out the the probing point. The evidence of these supercurrents was obtained by an observation of the different relaxation behaviors of the magnon BEC at different heating times.

Now, by adding an external heat source, namely a second laser, we are able to perform spatial-resolved measurements and are therefore able to study the transport properties of the magnon supercurrents. We present here the measured data of the performed experiment.

[1] Bozhko *et al.* Nature Physics **12**, 1057 (2016)

MA 64.60 Fri 9:30 P2-EG

Magneto-dynamics of single crystal Gadolinium Iron Garnet — •Lukas Liensberger[1,2], Hannes Maier-Flaig[1,2], Andreas Erb[1], Stephan Geprägs[1,2], Sebastian T.B. Goennenwein[1,2,3,4], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Institut für Festkörperphysik, Technische Universität Dresden, Germany — [4]Nanosystems Initiative Munich, Munich, Germany

For many decades, the ability to tune the magneto-dynamical properties of doped rare-earth iron garnets has triggered a multitude of investigations and resulted in numerous applications. One prime example for tunable magnetic properties in the iron garnets is Gadolinium Iron Garnet (GdIG) because its sublattice magnetizations can be controlled via temperature. In particular, the net magnetization M_{net} of GdIG exhibits a compensation point at the so-called compensation temperature ($T_{\mathrm{comp}} = 289\,\mathrm{K}$) where M_{net} vanishes. We present an investigation of the magneto-dynamics of a single crystal GdIG disk using broadband magnetic resonance in the microwave frequency range as a function of temperature. Our measurements reveal that the magnetic eigenmodes of GdIG show a distinct evolution with temperature. Below 270K, the Gd sub-lattice magnetization dominates the total GdIG moment and we mainly observe a ferromagnetic-like mode. Near T_{comp}, the antiferromagnetic exchange modes of GdIG fall within our experimentally accessible frequency range. We quantitatively discuss the data and model the observed resonance modes.

MA 64.61 Fri 9:30 P2-EG

Temperature dependence of magnetic damping in yttrium iron garnet spheres — •Hannes Maier-Flaig[1,2], Stefan Klingler[1,2], Carsten Dubs[3], Oleksii Surzhenko[3], Mathias Weiler[1,2], Sebastian T.B. Goennenwein[1,2,4,5], Rudolf Gross[1,2,5], and Hans Huebl[1,2,5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Germany — [3]INNOVENT e.V. Technologieentwicklung, Jena, Germany — [4]Institut für Festköperphysik, Technische Universität Dresden, Germany — [5]Nanosystems Initiative Munich, München, Germany

The ferrimagnetic insulator Yttrium iron garnet (YIG) is considered one of the prototypical material systems for applications in spintronics and quantum information processing. In order to predict and optimize the performance of devices, detailed knowledge of the frequency and temperature dependence of the damping in YIG is of key importance. We investigate the microwave absorption spectrum of an YIG sphere as a function of temperature and frequency. We observe the typical magnetostatic magnon modes of a YIG sphere. Above 100 K, their magnetic resonance linewidth scales linearly with temperature and also shows a Gilbert-like linear frequency dependence. At lower temperatures, the linewidth exhibits a characteristic peak that coincides with a non-Gilbert like magnetic resonance damping mechanism. We model the temperature and frequency evolution of the linewidth assuming a slowly relaxing rare-earth impurity and either the Kasuya-LeCraw mechanism or the scattering with optical magnons.

MA 64.62 Fri 9:30 P2-EG

Progress in wavevector-resolved Brillouin light scattering spectroscopy of magnon gases and condensates — •Pascal Frey[1], Dmytro A. Bozhko[1,2], Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

Brillouin light scattering spectroscopy is a powerful technique for studying dynamic properties of magnetic materials and devices with both frequency and wavevector resolution. Here, we report on an improvement of this technique in a backward scattering geometry. Previously, we presented a method to detect magnons with wavevectors collinear to the applied magnetic field by turning the entire setup, including the magnet system. Here, instead of rotating the magnet itself, we realized a method where we rotate a probing beam around a sample. The method allows for probing of arbitrary magnetized samples in a wide range of magnetic fields with improved resolution. For further refinement, we place a dielectric mirror beneath the sample to enhance the signal from the backward scattering process. To minimize optical aberrations, we strive for deposition of a dielectric mirror directly on the sample. In combination with a new generation of multipass tandem Fabry-Pérot interferometry, the reported wavevector-resolved technique promises significant improvement in the determination of magnon states in energy and phase space. The work is supported by the European Research Council within the ERC Advanced Grant ”Supercurrents of Magnon Condensates for Advanced Magnonics”.

MA 64.63 Fri 9:30 P2-EG

Surface acoustic wave devices for magnon-phonon interaction — •Clemens Mühlenhoff[1,2], Stefan Klingler[1,2], Hans Huebl[1,2,3], Rudolf Gross[1,2,3], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Inititative Munich, München, Germany

Surface acoustic wave (SAW) delay line bandpass filters are of major importance in today’s communication technology. From a more fundamental perspective, SAWs represent coherent phonon states at GHz frequencies which can be employed to study the interplay of phonons with other degrees of freedom in a solid state environment. In particular, we are interested in the magnon-phonon interaction within a ferromagnetic thin film. We employ electron-beam lithography to define SAW delay lines on a $LiNbO_3$ substrate. The interdigital transducers (IDTs) converting the electrical stimulus to a SAW are realized with metallic electrodes with a width of less than 1 μm. We present fabrication strategies and microwave transmission measurements to quantify the performance of our SAW delay lines. Our devices are capable of generating and detecting SAWs at frequencies exceeding 10 GHz. This frequency range is ideally suited for the study of phonon-driven magnetization dynamics in a ferromagnetic thin film deposited in the area between the two IDTs. This dynamics is induced by the resonant interaction of the coherent phonon drive and the magnons at the ferromagnetic resonance frequency.

MA 64.64 Fri 9:30 P2-EG

Driving Ultrafast Magnetization Dynamics of Gd with Near-Infrared Laser Pulses — •Kamil Bobowski[1], Beatrice Andres[1], Robert Carley[2], Björn Frietsch[1], Markus Gleich[1], Cephise Cacho[3], Emma Springate[3], Serguei Molodtsov[2], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld — [3]Rutherford Appleton Laboratory, Didcot, OX11 0QX, UK

We investigated the ultrafast magnetization dynamics of a single-crystalline Gd(0001) thin film with the high-harmonic source at the Artemis Facility at Rutherford Appleton Laboratory. In contrast to most studies, we employ 1300-nm pump pulses. In agreement with our earlier measurements, we observe a considerable redistribution of the electronic population around the Fermi level and a fast decrease of the exchange splitting of the valence bands [1]. However, within the first 200 fs we find an increase of the exchange splitting, which was also observed in MOKE experiments [2], caused by a dip in the majority band binding energy. In addition, we observe oscillations in the energetic position of the valence bands and the surface state before excitation. We discuss these oscillations in the framework of ponderomotive acceleration by a transient grating formed by the interference of the incoming and outgoing pump pulses [3].

[1] R. Carley *et. al.*, Phys. Rev. Lett. **109**, 057401 (2012).
[2] M. Sultan *et. al.*, Phys. Rev. B **85**, 184407 (2012).
[3] U. Bovensiepen *et. al.*, Phys. Rev. B **79**, 045415 (2009).

MA 64.65 Fri 9:30 P2-EG

Polarization Control of High Harmonics for Ultrafast Magnetic Imaging — •Christina Nolte[1], Sergey Zayko[2], Ofer Kfir[2,3], Sascha Schäfer[2], Daniel Steil[1], Birgit Hebler[4], Manfred Albrecht[4], Oren Cohen[3], Stefan Mathias[1], and Claus Ropers[2] — [1]1st Physical Institute, University of Göttingen — [2]4th Physical Institute, University of Göttingen — [3]Physics Department, Technion, Israel — [4]Institute of of Physics, University of Augsburg

The generation of circularly polarized extreme ultraviolet and soft X-ray radiation from high-harmonic light sources [1,2] in combination with lensless imaging techniques opens a new and powerful route for the spatially resolved study of ultrafast magnetization dynamics [3].

We utilize a stable and compact method of generating bright circularly polarized high harmonics [4] and extend the approach to tailor the radiation ellipticity by a precise control of recollision trajectories. We characterize the XUV polarization in two spectral regions (25-30 eV and 50-60 eV) using two methods: (i) polarization selective nanoscale waveguides [5] and (ii) magneto-optical activity in Co [1]. In addition, we present diffraction data and discuss current progress towards the imaging of magnetic structures.

[1] O. Kfir et al., Nature Photonics 9, 99-105 (2015)
[2] T. Fan et al., PNAS 112, 14206 (2015)
[3] S. Mathias et al., JESRP 189, 164 (2013)
[4] O. Kfir et al., Appl. Phys. Lett. 108, 211106 (2016)
[5] S. Zayko et al., Optica 3, 239 (2016)

MA 64.66 Fri 9:30 P2-EG

Ultrafast demagnetization dynamics in non-collinear magnetic multilayers — •Sakshath Sadashivaiah[1], Martin Steihl[1], Fabian Ganss[2,3], David Schummer[1], Moritz Barkowski[1], Ute Bierbrauer[1], Manfred Albrecht[3], Mirko Cinchetti[4], Benjamin Stadtmueller[1], Stefan Mathias[5], and Martin Aeschlimann[1] — [1]T U Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]T U Chemnitz, 09107 Chemnitz, Germany — [3]University of Augsburg, Universitätsstraße 1 Nord, 86159 Chemnitz, Germany — [4]T U Dortmund, 44221 Dortmund, Germany — [5]University of Göttingen, Friedrich Hund Platz 1, 37077 Göttingen, Germany

Non-collinear magnetic multilayers are ideal sample systems to study optically excited spin currents in magnetic materials. Our sample system consists of two magnetic layers, a Pd/Co multilayer layer films and a NiFe alloy, separated by a non-magnetic spacer layer. Using an external magnetic field, the relative magnetization direction of both magnetic layers can be tuned from non-collinear or to collinear. Optical excitation of the NiFe layer by fs laser pluses creates spin currents that are injected into the subsequent layers. Using the complex nature of the Kerr response [1], we study the magnetization dynamics of individual layers. This allows us to determine the role of ultrafast spin currents for the fs-demagnetization in the collinear and non-collinear configurations, as well as for different spacer materials.

References: J. Hamrle et al, Phys. Rev. B 66, 224423 (2002)

MA 64.67 Fri 9:30 P2-EG

Influence of the pump pulse photon energy on the ultrafast magnetization dynamics of gadolinium — •Markus Gleich[1], Kamil Bobowski[1], Niko Pontius[2], Christian Schüssler-Langeheine[2], Christoph Trabant[1], Marko Wietstruk[1], Björn Frietsch[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 have investigated the dependence of the pump pulse photon energy on the ultrafast magnetization dynamics of gadolinium. Single-crystalline Gd(0001) thin films were grown on a W(110) substrate. This allows us to study the magnetization dynamics by X-ray magnetic circular dichroism in reflection at the FEMTOSPEX facility of BESSY II. To clarify the role of electron transport, we performed simulations of the magnetization dynamics based on the microscopic three temperature model (M3TM) [1]. The M3TM was modified and extended to include the laser excitation process [2]. To reproduce the measured dynamics, we have varied several parameters such as the thermal conductivity and the heat capacity.

[1] B. Koopmans *et al.*, Nat. Mater. **9**, 259–265 (2010).
[2] Y. P. Meshcheryakov *et al.*, Appl. Phys. A **82**, 363–368 (2005).

MA 64.68 Fri 9:30 P2-EG

Extraction of Magnetic Nanoparticles from Magnetotactic Bacteria — •Lea Schwengels, Nadja Juric, Maryam Youhannayee, and Mathias Getzlaff — Institute of Applied Physics, Heinrich-Heine-Universität, Düsseldorf, Germany

Nanoparticles attract fascinating attention because of their capability in using for biological and medical application and research. Therefore, it seems to be promising to apply magnetic nanoparticles for different cancer treatments like hypothermia. Our research deals with the extraction and separation of chains of magnetite nanoparticles from magnetotactic bacteria (MTB) called Magnetospirillum magnetotacticum (MS-1) and subsequently the extraction of single magnetic nanoparticles from these obtained magnetosomes. Cultured Magnetospirillum magnetotacticum were purchased from DSMZ as an actively growing culture in specific liquid medium. In our research we use two different techniques to separate the nanoparticles from bacteria, ultrasonic and applying a combination of lysozyme and EDTA (Ethylenediaminetetraacetic). The combination of using lysozyme and EDTA represents a useful method to extract the magnetosome chains from our enriched bacteria without affecting the magnetite nanoparticle and its membrane. Using ultrasonic cause the lysis of bacteria and separation of magnetosome chains who are still surrounded by cell residues. Transmission electron microscopy has been applied in order to characterize the morphological structure of magnetite nanoparticles like shape and size.

MA 64.69 Fri 9:30 P2-EG

Stabilization of phase noise in vortex spin torque nano oscillators by a Phase Locked Loop — Martin Kreissig[2], •Steffen Wittrock[1], Romain Lebrun[1], Samh Menshawy[1], Karla Merazzo-Jaimes[3], Marie-Claire Cyrille[4], Ricardo Ferreira[5], Frank Ellinger[2], Paolo Bortolotti[1], Ursula Ebels[3], and Vincent Cros[1] — [1]Unité Mixte de Physique CNRS/Thales, Univ. Paris-Sud, Univ. Paris-Saclay, 91767 Palaiseau, France — [2]Chair for Circuit Design and Network Theory, Technische Univ. Dresden, 01062 Dresden, Germany — [3]Univ. Grenoble Alpes, CEA, INAC-SPINTEC, CNRS, SPINTEC, 38000 Grenoble, France

— [4]Univ. Grenoble Alpes, CEA-LETI MINATEC-CAMPUS, 38000 Grenoble, France — [5]International Iberian Nanotechnology Laboratory (INL), 471531 Braga, Portugal

After a decade of research, large expectations have been anticipated on how the rich physics of spin transfer induced magnetization dynamics could give birth to a new generation of multi-functional microwave spintronic devices. One major issue of spin-torque nano-oscillators (STNOs) is their relatively poor spectral coherence given by their highly nonlinear behavior. Within this work, we tackle this concern and could efficiently control the phase noise of vortex based STNOs by implementation of an integrated Phase Locked Loop (PLL) circuit. Focussing on vortex based STOs presenting higher spectral coherences than other kinds of STOs, a reduction of phase noise by more than 50dB at 10kHz from the carrier frequency is achieved under various field and current conditions.

MA 65: Poster 2

Time: Friday 9:30–13:00 Location: P2-OG1

MA 65.1 Fri 9:30 P2-OG1

Behavior of silica-based magneto-optical fluids influenced by dynamically changing magnetic stray field landscapes — •Iris Koch[1], Karl Sebastian Mandel[2], Tim Granath[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Fraunhofer Institute for Silicate Research ISC, Neunerplatz 2, D-97082 Würzburg

The microscopic motion of silica-based superparamagnetic rods (SR) in aqueous solution and their resulting macroscopic magneto-optical behavior were manipulated by using specially designed magnetic field landscapes (MFL). These MFL originate from a superposition of magnetic stray fields emerging from micromagnetically stripe-patterned exchange bias (EB) bilayer systems [1] and time-dependent external magnetic fields. The SR were found to arrange in parallel rows above the respective domain walls emerging from the EB substrate's surface. By applying defined external magnetic field pulses, the orientation and localization of these rows can be varied and, thereby, cause significant changes of the macroscopical optical properties of the fluid. The obtained results are promising for the future development of remotely switchable optical filter systems.

[1] D. Holzinger et al., J. Appl. Phys. 114, 1 (2013)

MA 65.2 Fri 9:30 P2-OG1

Magnetic properties of porphyrin magnetite nanocomposites — •Apoorva Sharma[1], Chalathan Saengruengrit[2], Patrick Matthes[3], Numpon Insin[2], Patchanita Thamyongkit[2], Dietrich R.T. Zahn[1], Georgeta Salvan[1], and Setfan Krause[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Department of Chemistry, Chulalongkorn University, 10330 Bangkok, Thailand — [3]Fraunhofer Institute for Electronic Nano Systems, 09126 Chemnitz, Germany

Since the advent of superparamagnetic nanoparticles, their properties have been vastly exploited by both industries and the scientific community. However, very few investigations are so far focused on the integration of such magnetic nanoparticles in an organic matrix for bio-medical applications. We hereby present our work conducted on porphyrin magnetite nanocomposites. The binding of magnetite particles to porphyrin was confirmed by fluorescence microscopy. The magnetic properties of nanoparticles with different geometries (cubes and spheres), sizes (10 nm and 25 nm), and cladding was investigated with superconducting quantum interference device - vibrating sample magnetometry (SQUID-VSM). These properties were observed to be insignificantly influenced by the addition of porphyrin. Furthermore, a comprehensive study of the interaction behaviour among these nanoparticles was performed using the first order reversal curve measurement technique (FORC) [1].

[1]C. R. Pike et al., J. Appl. Phys., vol. 85, no. 9, 1999.

MA 65.3 Fri 9:30 P2-OG1

Controlling the magnetic anisotropy of adsorbed Fe porphyrins by a ring-closure reaction — •Lucas M. Arruda[1], Md. Ehesan Ali[2], Matthias Bernien[1], Fabian Nickel[1], Jens Kopprasch[1], Peter M. Oppeneer[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, 75120 Uppsala, Sweden

Metalloporphyrins' stability and tunability make them well-suited candidates for use in molecular spintronics. In this context, the understanding of the on-surface properties and reactions of such systems is of great relevance. In this work we investigate the intramolecular reaction mediated by thermal stimulation undergone by iron octaethylporphyrin adsorbed onto a Au(111) single crystal substrate. Through a ring-closure process, the molecule turns into iron tetrabenzoporphyrin when subjected to an annealing temperature of 550 K [1]. Near-edge x-ray absorption fine structure, x-ray magnetic circular dichroism, and density-functional-theory-calculated density of states (DOS) results are presented to display the modifications resulting from this process. We find the magnetic anisotropy of the molecule after ring closure is reduced by a factor of six, while the iron magnetic moment is substantially increased. — Financial support by project VEKMAG (BMBF 05K13KEA) and CAPES is gratefully acknowledged.

[1] B. W. Heinrich *et al.*, Nano Lett. 13 (10), 4840 (2013).

MA 65.4 Fri 9:30 P2-OG1

The Emegence of Cooperativity in the Coverage-Dependent Temperature and Light-Induced Spin-State Switching of an Fe(II) Complex Adsorbed on a Graphite Surface — •Lalminthang Kipgen[1], Holger Naggert[2], Matthias Bernien[1], Fabian Nickel[1], Lucas M. Arruda[1], Andrew J. Britton[1], Sascha Ossinger[2], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut für Anorganische Chemie, Christian-Albrechts Universität zu Kiel, 24098 Kiel, Germany

The spin-state manipulation from high-spin state (HS, S=2) to low-spin state (LS, S=0) or vice versa of spin crossover molecules adsorbed on a surface has been of much interest due to its potential for applications in spintronic devices. We report on the complete spin-state switching from the sub-monolayer to multilayer coverage of an Fe(II) complex deposited on a highly oriented pyrolytic graphite surface with temperature and light. For a sub-monolayer coverage, the thermal spin transition is rather gradual between 300 K to 70 K and can be fitted well as a system of non-interacting molecules along the Vant Hoff's model. With the increased in coverage, the transition becomes more abrupt, which is attributed to increase cooperativity between the molecules.

MA 65.5 Fri 9:30 P2-OG1

Atomistic simulation of finite temperature magnetism of nanoparticles — •András Lászlóffy, László Udvardi, and László Szunyogh — Budapest University of Technology and Economics, Budapest, Hungary

Recent experimental efforts focus on scaling down the size of spintronics and magnetic logics devices to atomic scales to maintain technological development, which requires also intensive theoretical studies. By combining the spin-cluster expansion with the relativistic local moment scheme we developed a technique to determine suitable spin models for small embedded clusters of arbitrary geometry. We calculated the spin model of uncovered and covered hexagonal Co clusters on Au(111) surface and show that the parameters strongly depend on the local environment, especially on the coordination number of the magnetic atoms. In particular, the Co clusters capped by Au atoms display strong out-of-plane magnetic anisotropy. We performed Monte Carlo simulations to calculate the temperature dependent magnetization of the systems. We found that the blocking temperature of the covered clusters with perpendicular magnetic anisotropy can be determined by calculating the variance of the magnetization in the easy direction, since its inflection point is related to the magnetic anisotropy energy of the system. The average time of the spin reversals satisfy the Néel–Arrhenius law with an energy barrier slightly higher than the magnetic anisotropy energies of the clusters.[1]

[1] A. Lászlóffy, L. Udvardi, L. Szunyogh: arXiv: 1611.09199 (2016)

MA 65.6 Fri 9:30 P2-OG1

Monte-Carlo simulation studies on the superspin structure of 3D nanoparticle supercrystals — •Mauricio Cattaneo, Michael Smik, Oleg Petracic, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich

The assembly of magnetic nanoparticles into large 3D structures constitutes a novel way of fabricating artificial materials that show properties that are not found in conventional systems. A detailed understanding of the magnetic properties is impeded by the huge number of contributing parameters as well as the difficulty in probing the internal magnetic structure in situ. Monte-Carlo simulations offer the possibility to predict numerically possible magnetic ground states. Sufficiently small nanoparticles can be considered as single domain which may be modelled as an effective superspin. In contrast to atomic spins, the dominating inter-particle interaction is the dipole-dipole interaction. We simulated regularly arranged supercrystals of iron oxide nanoparticles with diameters between 10-20nm with various supercrystal structures and with various easy-axis orientations. Using the Metropolis scheme, we simulated the temperature dependent magnetization and ac susceptibility at various applied magnetic fields. The results are compared to measurements of experimental nanoparticle supercrystals.

MA 65.7 Fri 9:30 P2-OG1

Magnetic properties of wet-chemically prepared nanoparticles — •Adrian Jaspers, Maryam Youhannayee, and Mathias Getzlaff — Institute of Applied Physics, Heinrich-Heine-Universität, Düsseldorf, Germany

The magneto-optical Kerr effect (MOKE) is a convenient method to investigate the magnetic properties of magnetic systems such as ferromagnetic thin film and magnetic nanoparticles. In our research, a transverse magneto-optic Kerr effect (TMOKE) setup has been constructed in order to measure magnetic hysteresis loops by the intensity of a laser beam reflected of its surface. The magnetic particles consist of magnetite which have a wide application spectrum in biology and medicine. They have been prepared in a wet-chemical way (coopreciptation) using Iron(II) sulfate and Iron(III) chloride which were mixed thoroughly initially. Subsequently, ammonium has been added for formation of magnetite nanoparticles. In the following step, a few drops of nanoparticle solution have been applied on silicon wafer and dried under vacuum condition to obtain non-oxidized homogenous samples. The measuring procedure was run by a LabVIEW program which operated a bipolar power supply attached to the magnetic coils. The setup delivered results with a good signal-to-noise ratio even without utilizing any amplification devices.

MA 65.8 Fri 9:30 P2-OG1

Magnetization behavior and interactions of single magnetic nanodots — •Stefan Freercks[1], Philipp Staeck[1], Carsten Thönnissen[1], Eva-Sophie Wilhelm[1], Alexander Neumann[1,2], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Germany — [2]Institut für Medizintechnik, Universität zu Lübeck, Germany

We use the anomalous Hall-effect to measure the magnetization behavior of single magnetic nanodots with a uniaxial anisotropy perpendicular to the film plane in the blocked and the superparamagnetic state [1]. The nanodots and Hall bars are created by electron beam lithography and ion milling from thin Pt/Co/Pt multilayers. The diameter of the dots can be tuned down to 20 nm. Single nanodots as well as ensembles of a few nanodots have been investigated from 2.5 K to room temperature. The switching behavior of a single blocked nanodot has been studied as a function of field direction in three dimensions and differences to the model of Stoner-Wohlfarth are found [2]. In previous experiments interactions between nanodots were found [3]. Here the influence of the stray field of two blocked dots on the superparamagnetic switching behavior of a third dot is examined. Residual fields of the nanodots can be determined and give information on the internal dot structure. Funding by DFG via SFB 668 is gratefully acknowledged. [1] A. Neumann *et al.* Nano Letters. **13**, p2199-2203, (2014). [2] E. C. Stoner and E. P. Wohlfarth, Philos. Trans. R. Soc. London, Ser. A **240**, 599 (1948). [3] A. Neumann *et al.* New J. Phys. **16**, 083012 (2014).

MA 65.9 Fri 9:30 P2-OG1

Magnetic and morphological characterization of magnetite nanoparticles with ligand shell — •Stanislav Emelianov, Maryam Youhannayee, and Mathias Getzlaff — Institute of Applied Physics, Heinrich-Heine-Universität, Düsseldorf, Germany

Magnetic properties of nanoparticles are of big interest for scientists due to its wide application in different field such as medicine. In our research, magnetic nanoparticles are obtained by wet chemical synthesis (coprecipitation) using the following procedure: Ammonium hydroxide drop wised in Ferric Chloride and Ferrous Sulphate mixed solution. All procedures of synthesis were carried out in the presence of nitrogen. In order to increase the biocompatibility and to decrease the toxicity of them, the particles have been coated with Aminosilane shell. We investigated magnetic properties of iron oxide nanoparticles by means of the transverse magneto-optic Kerr effect (TMOKE) which is based on the analysis of p-polarized laser beam intensity after interaction with magnetic samples. To evaluate physical and morphological characterization of the particles, DLS (Dynamic Light Scattering) and TEM (Transmission Electron Microscopy) techniques are involved, in order to determine shape, size and structure of the particles and to observe particle-cluster formation.

MA 65.10 Fri 9:30 P2-OG1

Dilatometry in very high magnetic fields ... an overview — •Mathias Doerr[1], Sergey Granovsky[1], Martin Rotter[1,2], Thomas Stöter[1], Sergey Zherlitsyn[3], and Zhaosheng Wang[3] — [1]Technische Universität Dresden, Institut für Festkörperphysik, D-01062 Dresden, Germany — [2]McPhase-project (www.mcphase.de) Dresden, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Hochfeld-Magnetlabor (HLD-EMFL), PF 510119, D-01314 Dresden, Germany

Investigations of the changes in lattice constants or crystal symmetries of solids complement macroscopic measurements of electronic properties and often accompany ultrasound experiments. We give an overview on how the dilatometric methods have been developed in the last decade. The capacitive dilatometry can be used in steady fields with a resolution better than 10^{-8}. Especially for the highest available (pulsed) fields of about 100 T, optical methods, such as for example the FBG (fibre bragg grating) technology, were developed with a resolution better than 10^{-6}. Modern dilatometer constructions with a diameter of 5 mm allow to measure longitudinal and transversal components of the general striction tensor. Additionally, techniques to measure magnetostriction under pressure up to the highest fields are tested by scientific groups now. New results (GdSb, $CeCu_2Ge_2$, $Ho_2Ti_2O_7$ etc.) are discussed. The data are important to determine magnetic phase diagrams or show how lattice distortions influence the high-field properties of solids.

MA 65.11 Fri 9:30 P2-OG1

Quantitative Imaging of Magnetic Nanostructures Using Magneto Optical Indicator Film Techniques — •Manuela Gerken[1], Sascha Gorny[1], Sandra Lindner[2], Sibylle Sievers[1], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Matesy GmbH, Otto-Schott-Straße 13, 07745 Jena

The magneto-optical indicator film (MOIF) technique is a versatile tool for imaging magnetic domain structures. Optimized sensor films combined with correction schemes to compensate the influence of the finite sensor thickness allow to measure perpendicular stray field components with a spatial resolution down to the sub μm scale. However, present calibration schemes neglect in-plane stray field components. Therefore, a quantitative analysis of stray field data above micropatterned magnetic materials creates additional difficulties, since the closure of the flux lines leads to a rapidly spatially varying direction of the magnetic field H(x). To understand the sensor response on such arbitrary stray fields the full anisotropy tensor and the magnetic history of the sensor material have to be known. We will present results on the FMR based analysis of sensor materials and a thereon based sensor calibration scheme for vectorial stray fields. But, even if the sensor response function is understood, the inversion from contrast to stray field in gereral is not unique. Conditions which allow a reconstruction of the magnetic field and the underlying domain pattern will be discussed.

MA 65.12 Fri 9:30 P2-OG1

Microwave interferometry for high sensitivity VNA-FMR measurements — •Taras Holoyad, Joschua Kurda, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Vector network analyzer ferromagnetic resonance (VNA-FMR) using coplanar waveguides (CPW) is widely used to analyze ferromagnetic film parameters. This is of particular interest in the area of patterned magnetic nanostructures, where, however, due to the small volume, the absorption inn FMR is low and the FMR signal is superimposed by the excitation signal, limiting the sensitivity. Here, a promissing approach is microwave interferometry [1]. In the present work, we compare two techniques to generate the reference signal to interfere with the signal of the measurement path:

(I) A reference signal is generated in a second microwave path with the same geometry as the measurement path, including an identical but empty CPW. It is, however, extended by 0.5 m of an rf coaxial cable. This path length difference leads to a frequency dependent phase difference of the two paths in regular frequency intervals. (II) The second technique uses a fully synthetic reference signal generated by a second phase coherent microwave source with adjustable attenuation.

Our experiments reveal an improvement of the sensitivity by up to 2 orders in magnitude. The feasibility of both techniques is discussed.

[1] S. Tamaru et al, Ultrahigh Sensitivity Ferromagnetic Resonance Measurement based on Microwave Interferometer, IEEE Magn. Lett., Volume 5 (2014).

MA 65.13 Fri 9:30 P2-OG1

Element specific magnetometry of buried layers by HAXPES — •Andrei Gloskovskii[1], Gerhard H. Fecher[2], and Wolfgang Drube[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

The electronic properties of buried magnetic nano-layers were studied using the linear magnetic dichroism (LMD) in the angular distribution of photoemitted Fe, Co, and Mn $2p$ electrons from a CoFe-IrMn multi-layered sample. The buried layers were probed using hard X-ray photoelectron spectroscopy, HAXPES, at the undulator beamline P09 of the 3^{rd} generation storage ring PETRA III.

In general, the intensity and shape of photoelectron lines of magnetic materials depend on the relative orientation of the sample magnetisation, the X-ray beam polarisation and the spectrometer axis, i.e. the electron emission direction. The highest LMD value was obtained for the Fe $2p_{3/2}$ line measured with the polarisation vector $\vec{\mathbf{E}} \parallel \vec{\mathbf{M}}$ versus $\vec{\mathbf{E}} \perp \vec{\mathbf{M}}$. The dichroism value obtained for Fe $2p_{3/2}$ is 5.5%, for Co $2p_{3/2}$ it is 4.5%.

It is demonstrated that magnetic dichroism and spin-resolved HAXPES is an effective and powerful technique to perform element specific magnetometry of deeply buried ferromagnetic and antiferromagnetic magnetic materials and multilayered spintronics devices, which are inaccessible with conventional soft X-ray photoelectron spectroscopy. It allows to determine the relative orientation of the magnetisation in different layers in a complex nano-structured sample.

MA 65.14 Fri 9:30 P2-OG1

The quadratic magnetooptic tensor of cubic materials without inversion symmetry — •Robin Silber[1,2], Jan-Oliver Dreessen[2], Jaromír Pištora[1], Günter Reiss[2], Martin Veis[3], Jaroslav Hamrle[3], and Timo Kuschel[2,4] — [1]VSB - Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University, Prague, Czech Republic — [4]University of Groningen, The Netherlands

The permittivity tensor of a magnetized crystal could be described by a Taylor series: $\varepsilon_{ij} = \varepsilon_{ij}^{(0)} + \varepsilon_{ij}^{(1)} + \varepsilon_{ij}^{(2)} + \ldots$, where the superscript denotes the order in magnetization (**M**). The shape of $\varepsilon_{ij}^{(2)}$ is determined by the so-called quadratic magnetooptic (MO) tensor G_{ijkl} [1]. This quadratic MO tensor for cubic materials with and without inversion symmetry differ in the parameter $\Delta\Gamma = (G_{12} - G_{21})$ [2], being zero for cubic material with inversion symmetry as $G_{12} = G_{21}$. The $\Delta\Gamma$ parameter was predicted by symmetry arguments of the structure, but no experimental determination method exists so far. Here, we propose a new measurement procedure of magnetooptic Kerr effect (MOKE), allowing us to separate contribution of $\Delta\Gamma$ to overall MOKE signal.

[1] Š. Višňovský, Czech. J. Phys. B 36, 1424 (1986)
[2] J. Hamrlová et al., Phys. Status Solidi B 250, 2194 (2013)

MA 65.15 Fri 9:30 P2-OG1

FMR identification of skyrmionic states in confined helimagnetic nanostructures — •Marijan Beg[1], David I. Cortés-Ortuño[1], Weiwei Wang[1,2], Rebecca Carey[1], Mark Vousden[1], Ondrej Hovorka[1], and Hans Fangohr[1] — [1]Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, United Kingdom — [2]Department of Physics, Ningbo University, Ningbo, 315211, China

One of the challenges in the study of skyrmionic states in confined helimagnetic nanostructures is the detection of which state emerged in the studied sample. In this work, we explore how measuring resonance frequencies can contribute to the identification of the emergent state. We compare the power spectral densities of an incomplete Skyrmion (iSk) (also called the quasi-ferromagnetic or edged vortex state) and isolated Skyrmion (Sk) states in a 100 nm diameter FeGe disk sample with 10 nm thickness at different external magnetic field values using our full three-dimensional micromagnetic model. In this sample size and at all simulated external magnetic field values, the Sk state is metastable and the iSk state is the ground state. We discuss the comparison between iSk and Sk power spectral densities and observe several key differences in power spectral densities that can contribute to the experimental identification of the state present in the studied sample by measuring the resonance frequencies. This work was supported by the EPSRC's EP/G03690X/1 and EP/N032128/1 grants and the Horizon 2020 European Research Infrastructure project (676541).

MA 65.16 Fri 9:30 P2-OG1

Quantitative Analysis of Magnetic Nanoparticles by Means of the Magnetic Force Microscopy — •Runbang Shao[1], Adrian Schillik[2], Benjamin Riedmüller[1], Ulrich Herr[1], and Berndt Koslowski[2] — [1]Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland — [2]Institut für Festkörperphysik, Universität Ulm, Ulm, Deutschland

Magnetic force microscopy (MFM) is a powerful tool to analyze magnetic structures down to the nano-scale. Unlike macroscopic magnetic characterization techniques such as SQUID and VSM, which only reveal average magnetic properties of a large ensemble of nanoparticles, MFM is able to characterize a single nanoparticle with respect to magnitude and orientation of magnetization. The recently proposed pseudo-pole model [1], which assumes that the tip can be represented by an infinitely high cone covered homogeneously with dipoles pointing to the tip of the cone, allows quantitative analysis of the cantilever frequency shift versus tip-sample distance curves. Nano-composites of ferromagnetic Co nanoparticles made by inert gas condensation and SiOx cover layers with different layer thicknesses have been investigated. The frequency shift-distance curves agree well with the predictions from the pseudo-pole model, yielding detailed information about size and magnetization of the nanoparticles, as well as their depth below the film surface. It is further demonstrated that superparamagnetic nanoparticles can also be analyzed by this method. [1] Häberle, Thomas, et al. "Towards quantitative magnetic force microscopy: theory and experiment." New Journal of Physics 14.4 (2012): 043044.

MA 65.17 Fri 9:30 P2-OG1

Design of a vector magnetometer for three dimensional magnetization measurements — •Markus Kleinhans, Marco Halder, Christopher Duvinage, and Christian Pfleiderer — Physik-Department, Technische Universitaet Muenchen, 85748 Garching, Germany

In magnetically ordered systems, the fundamental order parameter is the magnetization which is, in general, a three dimensonal vector quantity. Conventional magnetometers, however, typically are limited to the projection of the moment along the applied magnetic field hence missing key informations of systems such as Ising ferromagnets in transvers fields [1]. We report the design of a bespoke set of pickup coils for a vibrating sample magnetometer allowing for the simultaneous determination of all three components of the magnetization for temperatures down to 3 K and in fields up to 9 T. We demonstrate the potential of this technique by studying the anisotropic ferromagnets Co and $Nd_2Fe_{14}B$.

[1] Coldea *et al.*, Science **327**, 5962 (2010).

MA 65.18 Fri 9:30 P2-OG1

Spontaneous and field-induced magnetic phase transitions in $\mathbf{Dy_2Co_3Al_9}$ — •D.I. Gorbunov[1], M.S. Henriques[2], C. Salazar Mejía[1], J. Gronemann[1], A.V. Andreev[2], M. Uhlarz[1], Y. Skourski[1], and J. Wosnitza[1,3] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany — [2]Institute of Physics, Academy of Sciences, Na Slovance 2, 182 21 Prague, Czech Republic — [3]Institut für Festkörperphysik, TU Dresden, D-01062 Dresden, Germany

In the crystal structure of $Dy_2Co_3Al_9$, there are various Dy-Dy interatomic distances with similar values. Due to the poorly compensated exchange and anisotropy interactions acting on the Dy spins, a magnetically stable state is difficult to achieve and the system displays a number of spontaneous and field-induced magnetic phase transitions as revealed by means of magnetization, specific-heat, and electrical-resistivity measurements. Antiferromagnetic ordering sets in at the Néel temperature, $T_N = 6.2$ K, followed by two additional phase transitions at 5.2 and 3.7 K in zero field. In applied magnetic fields, new phases emerge. The field-dependent magnetization exhibits multiple jumps accompanied by large magnetoresistance changes. The magnetoresistance can be explained by modified conduction-electron spectra since the conduction electrons interact with the localized magnetic moments.

MA 65.19 Fri 9:30 P2-OG1

Chiral magnetism of Fe intercalated $TaSe_2$ and $NbSe_2$ — •Hemza Kouarta[1,2], Jonathan Chico[2], Hafid Belkhir[1], and Samir Lounis[2] — [1]Faculty of Science, Department of Physics, Laboratory Studies of Surfaces and Interfaces of Solid Materials (LESIMS), University of Badji Mokhtar, P.O. Box 12, Annaba 23000, Algeria — [2]Peter Grünberg Institut and Institute of Advanced Simulation, Forschungszentrum Jülich & JARA, D-52428, Jülich, Germany

Transition metal dichalcogenides have been extensively studied due to the quasi two dimensional structure of the trilayers that compose it. The intercalation of Fe in the Ta(Nb)Se_2 compounds, has been observed to give rise to ferromagnetic (antiferromagnetic) order, and in the case of Ta a large magnetrocrystalline anisotropy energy (MAE) has been measured[1].

We perform fully relativistic first-principles simulations on these two materials considering alloying Nb and Ta at different concentrations, i.e. $Fe_{1/4}Ta_{1-x}Nb_xSe_2$. We investigate the Heisenberg magnetic exchange interactions, Dzyaloshinkii-Moriya interactions and the MAE and shine light on their microscopic origins. All of that with the objective of studying the impact of substitutional disorder in the magnetic properties of these compounds, while also allowing the exploration of the phase transition between the ferromagnetic and antiferromagnetic states present in the stochiometric compounds.

[1] K.-T Ko et al.*Phys. Rev. Lett.*, **107**, 247201 (2011)

MA 65.20 Fri 9:30 P2-OG1

Microscopic View of Magnetic Anisotropy in Permalloy — •Debora C M Rodrigues[1,2], Angela B Klautau[2], Alexander Edström[1], Jan Rusz[1], Lars Nordström[1], Manuel Pereiro[1], Björgvin Hjörvarsson[1], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]Faculty of Physics, Federal University of Pará, Belém, Brazil

Permalloy (Py) is the common name for Fe-Ni alloys, with concentration of 80 % Ni and 20 % Fe, and known due to its vanishingly low magnetic anisotropy energy (MAE) and low damping parameter. Py may be viewed as a huge ensemble of interconnected clusters of Fe-Ni atoms distributed on an fcc lattice. Therefore, by means of relativistic first principles calculations, we investigated the microscopic origin of the vanishingly low magnetic anisotropy of Py. The study was focus on evaluating the orbital moment anisotropy of clusters composed by Fe and Ni, with different configurations, embedded in an effective medium of Py. The MAE is obtained by relating the orbital moment anisotropy and local magnetic anisotropy. As result, we found that the local MAE can be much larger than that of the Py bulk sample, and at least the same order order of magnitude than of Fe or Ni bulk. We discuss these results in terms of local symmetries of the alloy and conclude that the vanishingly small MAE would be the result of a proper configurational average.

MA 65.21 Fri 9:30 P2-OG1

Field-free manipulation of spin structure in perpendicularly magnetized thin films — •Mariia Filianina[1], Samridh Jaiswal[1,2], Tetsuya Hajiri[3], Alexander Kronenberg[1], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany. — [2]Singulus Technologies AG, Kahl am Main, 63796, Germany. — [3]Department of Crystalline Materials Science, Nagoya University, Nagoya 464-8603, Japan

Recently there has been an immense interest for efficient methods of magnetization reversal, in particular by means of electric fields, as recently realized in multiferroic systems. This approach is advantageous because of the low power required without any power-hungry constant current flow. It utilizes so called magnetostrictive coupling, which is the effect of lattice strain on magnetic properties resulting from spin-orbit interaction, such as anisotropy but also the Dzyaloshinskii-Moriya interaction (DMI). The DMI stabilizes chiral spin structures, in particular skyrmions, and possible applications can be facilitated by the control of this interaction [1,2].

In this contribution we report on manipulation of magnetization via electric field induced strain, observed for thin Co20Fe60B20 perpendicularly magnetized film, fabricated on top of the piezoelectric substrate with a W seed layer. The modification of the direct spin structure by strain was imaged by x-ray microscopy to reveal the impact of the strain on the anisotropy and DMI.

1. A. Fert et al., Nat. Nanotechnol. 8, 152 (2013).
2. S. Woo et al., Nat. Mater. 15, 501 (2016).

MA 65.22 Fri 9:30 P2-OG1

Quantifying the electric field induced change of magnetic anisotropy in ultrathin Fe layers — •Mirko Ribow, Liane Brandt, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics

The recent discovery of magneto-electric coupling in ultrathin ferromagnet-dielectric heterostructures has opened new ways to control the magnetic properties via electric fields. A possible application of this effect is magnetization control in ultra low power consumption spintronic devices. Here, we report on the quantitative evaluation of the electric field induced change of magnetic anisotropy (ECMA) in Au/MgO/Fe/Au(001) layers grown by molecular beam epitaxy. Fe layers in a thickness range of t = 0 - 7 monolayers were studied. In the analysis special care has been taken to exclude charge trapping effects, which can lead to an overestimation of the ECMA effect. In contrast to an expected 1/t dependence of the effect, our results demonstrate an increasing ECMA as function of thickness. This finding cannot be explained based on a modification of the electronic structure only at the surface of the Fe layer, instead it may be attributed to the electric tuning of quantum well states [1].

[1] U. Bauer et al., Phys. Rev. B., 89, 174402 (2014)

MA 65.23 Fri 9:30 P2-OG1

Probing the Spin Hall Effect of β-Tungsten by Terahertz Emission Spectroscopy — •Oliver Gückstock[1], Tom Seifert[1], Sebastian Dapper[2], Satya Prakash Bommanaboyena[2], Markus Meinert[2], and Tobias Kampfrath[1] — [1]Fritz Haber Institut, MPG, Berlin, Deutschland — [2]Universität Bielefeld, Bielefeld, Deutschland

The efficient conversion of spin into charge currents driven by spin-orbit interaction (SOI) will be highly important for future spin-based electronics [1]. Recently, much effort has been devoted to the identification of new large-SOI materials. One promising material is β-tungsten, for which large spin Hall angles (SHA) have been reported [2]. However, it remains unclear to which extent such a large SHA is caused by an increased SOI or by a decreased longitudinal conductivity. In our experiments, we employ femtosecond optical pulses to trigger ultrafast spin transport in magnetic thin-film stacks. Due to SOI, this spin current is partially converted into a transverse charge current which is monitored by detecting the concomitantly emitted THz electromagnetic radiation [3,4]. In particular, we study THz emission from bilayers of ferromagnetic cobalt-iron-boron and nonmagnetic β-tungsten with varying oxygen concentration. By additionally measuring the THz conductivity of these films, we are able to separate the influence of the spin-Hall conductivity and the longitudinal conductivity to the SHA.

References: [1] S.A. Wolf et al., Science 294.5546 (2001), [2] K. Demasius et al., Nature Comm. 7, 10644 (2016), [3] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013), [4] T. Seifert et al., Nature Phot. 10, 483 (2016)

MA 65.24 Fri 9:30 P2-OG1

Doping of perpendicularly magnetized ferrimagnetic Mn_3Ge thin films — •Jan Balluff, Markus Meinert, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

The Mn_3Ge compound[1] is interesting for spintronic applications in several ways. It combines a low saturation magnetization of $1\mu_B$ per unit cell with a high coercivity of more than 2T. Furthermore, it shows perpendicular anisotropy, which is preferable, e.g, for spin transfer torque switching in magnetic tunnel junctions. We report on a study of doping the compound to improve the magnetic properties. Using density functional theory we calculate defect formation energies for $Mn_{3-x}Y_xGe$, where Y are different dopants occupying either one of the two inequivalent Mn sites. In the case of Y=Ni, a reduction in the saturation magnetization is predicted.We prepared epitaxial thin films of

Ni-doped Mn_3Ge on $SrTiO_3$ substrates using magnetron co-sputtering for different Ni concentrations. Magnetization measurements using a vibrating sample magnetometer reveal the predicted reduction in the magnetization for low Ni concentrations x ≈ 0.2.

[1] H.Kurt et al., Appl. Phys. Lett. 101, 132410 (2012)

MA 65.25 Fri 9:30 P2-OG1

Magnetocrystalline anisotropy of ultrathin, epitaxial magnetite and iron films on MgO(001) — •Kristina Sprenger, Jari Rodewald, and Joachim Wollschläger — Fachbereich Physik, Universität Osnabrück, Barbarastraße 7, 49076 Osnabrück

Ferrimagnetic materials as magnetite are very important nowadays. Combined with the wide field of spintronics, it's an essential part of technological applications in many facets, for example in the development of non-decaying memories. For that it is very important to know the electric and magnetic properties of iron, magnetite and related materials.

In this work, the focus lies on the fabrication of Fe and Fe_3O_4 layers by reactive molecular beam epitaxy (RMBE) on MgO(001) and analyzing them towards their magnetic properties. For studying their chemical composition, x-ray photoelectron spectroscopy (XPS) is applied and the surface structure of the prepared films is characterized via low energy electron diffraction (LEED). The main focus lies on finding out about the magnetic properties of the thin films by vibrating sample magnetometry (VSM), ferromagnetic resonance (FMR) and the magneto-optical Kerr effect (MOKE).

The approach that is used focusses on the 360° in-plane orientation-dependent behaviour of all three measurement methods. Additionally, the dependency on the film thickness is evaluated. To do so, properties like remanence, coercivity and magnetocrystalline anisotropy, especially shifts in tetramerous and uniaxial anisotropy are analyzed in iron and magnetite films with different layer thicknesses.

MA 65.26 Fri 9:30 P2-OG1

Stripe domains in tetragonally distorted Fe-Co-C films with perpendicular anisotropy — •Volker Neu, Ludwig Reichel, Sebastian Fähler, Rudolf Schäfer, and Kornelius Nielsch — IFW Dresden, Institute for Metallic Materials

The tetragonal distortion of an epitaxially grown Fe-Co-C film introduces a significant perpendicular magnetic anisotropy into the otherwise cubic Fe-Co with low magnetocrystalline anisotropy. Unlike C-free films, which obtain their tetragonal distortion solely from lattice mismatch and which relaxes within a few nm, C-containing films maintain a crystallographic distortion of $(c/a)_{bct} = 1.03$ and a perpendicular magnetic anisotropy of ca. 0.4 MJ/m^3 even up to thicknesses of 100 nm [1]. We present the magnetic domain structure of such a $(Fe_{0.4}Co_{0.6})_{0.98}C_{0.02}$ film prepared on MgO(100) single crystal substrates. It has a thickness slightly above the critical stripe nucleation value, and hence the perpendicular anisotropy leads to a modulation of the out-of-plane magnetization in parallel stripes of 45 nm width, superimposed on large domains oriented in the film plane along the [110] and [1-10] direction. The analysis of such a multiscale domain pattern requires the combination of high resolution magnetic force microscopy (MFM) with its sensitivity to perpendicular stray fields and the large-view vectorial imaging capabilities of Kerr microscopy for in-plane magnetization. The details of the 90° and 180° boundaries of the large in-plane domains are resolved by MFM on a sub-50 nm level.
[1] L. Reichel *et al.* JAP 116 (2014) 213901.

MA 65.27 Fri 9:30 P2-OG1

Investigation of magnetic properties of epitaxial Fe_3O_4 and Fe_3O_4/NiO bilayers grown on MgO(001) and $SrTiO_3$(001) via VSM — •Kevin Ruwisch, Jari Rodewald, and Joachim Wollschläger — Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49079 Osnabrück, Germany

Magnetite as a ferrimagnet has become more important for industrial applications in spintronics over the years. For instance, it is used in magnetoresistive random-access memory (MRAM) consisting of magnetic tunnel junctions (MTJ). Thus, improving the magnetic properties of ferrimagnetic films for spintronic devices is very important.

Hence, in this work Fe_3O_4 and Fe_3O_4/NiO bilayers, grown by reactive molecular beam epitaxy (RMBE) on MgO(001) and $SrTiO_3$(001), are investigated via vibrating sample magnetometry (VSM).

One approach of characterizing the magnetic features of Fe_3O_4 and Fe_3O_4/NiO is to evaluate the impact of NiO towards coercivity, remanence and magnetocrystalline anisotropy. Here, Fe_3O_4/NiO/MgO exhibits 45°-rotated magnetic easy axes in ⟨110⟩ directions while thin magnetite films deposited on MgO(001) have easy axes in ⟨100⟩ directions. Furthermore, the difference in the magnetic properties of magnetite on both substrates is evaluated. It shows that a 45°-rotation, including larger absolute values in coercivity and remanence, takes place on $SrTiO_3$(001) in contrast to MgO(001). Additionally, the influence of the layer thickness of magnetite towards the magnetic behaviour is investigated in in-plane and out-of-plane-orientation with respect to the applied magnetic field.

MA 65.28 Fri 9:30 P2-OG1

Magnetocrystalline anisotropy in the nanolaminated magnetic Mn2GaC MAX phase — •Iuliia Novoselova[1], Ruslan Salikhov[1], Arni S. Ingason[2], Johanna Rosen[2], Ulf Wiedwald[1], Hongbin Zhang[3], and Michael Farle[1,4] — [1]Faculty of Physics, University Duisburg-Essen, Duisburg, Germany — [2]Thin Film Physics Division, Department of Physics, Linköping University, Linköping, Sweden — [3]Institute of Materials Science, Theory of Magnetic Materials Group, TU Darmstadt, Darmstadt, Germany — [4]Center for Functionalized Magnetic Materials, IKBFU, Kaliningrad, Russia

MAX phases ($M_{n+1}AX_n$, n = 1, 2, etc.) are inherently nanolaminated hexagonal compounds composed of early transition metals M, A-group elements and X refers to C or N. Due to the unique structure these materials share properties usually associated with ceramics and metals [1]. Ternary Mn_2GaC magnetic compounds have been synthesized recently as hetero-epitaxial films containing Mn as the exclusive M-element [2]. Using ferromagnetic resonance (FMR) we have studied magnetic anisotropy in the Mn_2GaC in comparison with $(Cr_{0.5}Mn_{0.5})_2GaC$ MAX phase [3]. We find a significant magnetocrystalline anisotropy energy density of 0.5 MJ/m^3 at the temperature below 200 K with the easy axis perpendicular to the c-axis. Such observation can be understood using the perturbation theory based on the first-principles calculations. This work is supported by DFG Grant SA 3095/2-1 and DAAD Programm 57214224. [1] M. W. Barsoum, Prog. Solid State Chem. 28, 201 (2000). [2] A. S. Ingason et al., MRL, 2, 89 (2014). [3] R. Salikhov et al., MRL, 3, 156 (2015).

MA 65.29 Fri 9:30 P2-OG1

Magnetic Anisotropy of Layered Chromium Trihalides — •Nils Richter[1,2], Franziska Racky[1], Daniel Weber[3], Clemens Wuth[4], Bettina V. Lotsch[3,5], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität, Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Mainz, Germany — [3]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [4]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Hamburg, Germany — [5]Department of Chemistry and Center for NanoScience, Ludwig-Maximilians-Universität, München, Germany

We comprehensively determine the magnetic properties of single crystals of the isostructural series of the compounds CrI_3, $CrBr_3$ and $CrCl_3$ to obtain a systematic overview. We find a strong anisotropy of the magnetization along different directions. A detailed analysis of the uniaxial anisotropy as a function of temperature between 5K and their respective critical magnetic ordering temperature allows us to explain the temperature evolution of the magnetization along different crystallographic axes. The in-depth understanding of the bulk magnetic properties serves as a basis for the future exploration of few- and monolayer counterparts of these crystals. Such magnetic van-der-Waals materials are extremely important for spintronic and magnetoelectronic applications [1].

[1] Felser, C. et al., Angew. Chem., Int. Ed. 46 (2007).

MA 65.30 Fri 9:30 P2-OG1

Ferromagnetism in Silicon Single Crystals with Positively Charged Vacancy Clusters — •Yu Liu[1], Xinghong Zhang[2], Quan Yuan[2], Jiecai Han[2], Shengqiang Zhou[1], and Bo Song[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Harbin Institute of Technology

Defect-induced ferromagnetism provides an alternative for organic and semiconductor spintronics. Here, we investigated the magnetism in Silicon after neutron irradiation and try to correlate the observed magnetism to particular defects in Si. Commercially available p-type Si single crystal wafer is cut into pieces for performing neutron irradiations. The magnetic impurities are ruled out as they can not be detected by secondary ion mass spectroscopy. With positron annihilation lifetime spectroscopy, the positron trapping center corresponding to lifetime 375 ps is assigned to a kind of stable vacancy clusters of hexagonal rings (V6) and its concentration is enhanced by increasing neutron doses. After irradiation, the samples still show strong diamagnetism. The weak ferromagnetic signal in Si after irradiation enhances and then weakens with increasing irradiation doses. The saturation magnetization at room temperature is almost the same as that at 5 K. The X-ray magnetic circular dichroism further provides the direct evidence that Silicon is the origin of this ferromagnetism. Using first-principles calculations, it is found that positively charged V6 brings the spin polarization and the defects have coupling with each other.

MA 65.31 Fri 9:30 P2-OG1

Possible Polaron Percolation in the Diluted Magnetic Semiconductors (Ga,Mn)As and (Ga,Mn)P — •Martin Lonsky[1], Jan Teschabai-Oglu[1], Klaus Pierz[2], Hans Werner Schumacher[2], Ye Yuan[3], Shengqiang Zhou[3], and Jens Müller[1] — [1]Physikalisches Institut, Goethe-Universität, Frankfurt (M), Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Diluted magnetic semiconductors combine the benefits of semiconducting and magnetic materials and therefore are promising candidates for spintronics applications. For instance, (Ga,Mn)As and (Ga,Mn)P exhibit long-range magnetic order between substitutional Mn ions mediated by holes. Despite intense research efforts, there is no consensus on the development of spontaneous magnetization. An intriguing theoretical concept is the percolation of magnetic polarons as a possible origin [1]. Motivated by results of a diverging 1/f-noise magnitude in the CMR material EuB_6, where the existence of percolating nanoscale magnetic clusters has been demonstrated [2], we study the low-frequency carrier dynamics by fluctuation spectroscopy. Besides insights into the defect physics of the materials, we find a power law scaling of the noise magnitude $S_R/R^2 \propto R^\omega$ at the percolation threshold p_c with a critical exponent $\omega = 3.7 \pm 0.3$ for (Ga,Mn)P, which we compare with the results for (Ga,Mn)As with delocalized carriers.

[1] A. Kaminski and S. Das Sarma, Phys. Rev. Lett. 88, 247202
[2] P. Das et al., Phys. Rev. B 86, 184425

MA 66: Poster 3

Time: Friday 9:30–13:00 Location: P2-OG2

MA 66.1 Fri 9:30 P2-OG2

Manipulation of AF-Coupled Thin Film Systems by Ion Beam Irradiation — •Leopold Koch[1,2], Fabian Samad[2], Benny Böhm[2], Fabian Ganss[2], Sri Sai Phani Kanth Arekapudi[2], Miriam Lenz[1], Sven Stienen[1], and Olav Hellwig[1,2] — [1]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [2]Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

The tuning of the magnetic properties of antiferromagnetically (AF) coupled multilayer films by ion beam irradiation has been investigated. Stacks of Co/Pd respectively Co/Pt multilayers, AF-coupled by Ru or Ir interlayers, have been useful for studying the energy contribution of interlayer exchange, perpendicular anisotropy and long range dipole interactions. The system shows a complex mixture of magnetic phases that can be tuned by the number of repeats of the multilayers (X). A lateral homogeneous AF remanent structure occurs for small X due to the dominance of the AF-coupling. For large X the demagnetisation energy prevails and ferromagnetic stripe domains evolve. With ion irradiation the balance of the energy contributions can be locally manipulated, thus a lateral heterogeneous structure of magnetic phases may be realised. Initial irradiation studies will be discussed.

MA 66.2 Fri 9:30 P2-OG2

Influence of oxygen content on magnetic properties in La2/3Sr1/3MnO3-δ thin films — •Lei Cao[1], Oleg Petracic[1], Alexander Weber[2], and Thomas Brückel[1,2] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich — [2]Jülich Centre for Neutron Science JCNS at Heinz Maier-Leibnitz Zentrum MLZ, Forschungszentrum Jülich GmbH, Garching

Complex oxides display a multitude of unique phenomena, such as various forms of magnetism, superconductivity, colossal magnetoresistance, ferroelectricity, and couplings between these states. While most studies on complex oxide thin films focus on the parameters of film deposition and the role of oxygen during preparation the role of oxygen content after sample preparation onto the physical properties is mostly unknown. We report on the fabrication of La2/3Sr1/3MnO3-δ thin films on SrTiO3 substrates by sputter deposition. Using an in-situ x-ray diffraction setup we investigate the crystallographic properties while annealing the samples in vacuum and at various temperatures. While annealing induces a desorption of oxygen, absorption of oxygen is realized in a controlled oxygen plasma of a sputtering setup. By employing superconducting quantum interference (SQUID) magnetometry and electrical resistivity measurements, we study the magnetic and transport properties of the as-prepared, annealed and plasma treated systems. We then relate the influence of oxygen absorption/desorption to the physical properties of the films.

MA 66.3 Fri 9:30 P2-OG2

Exchange bias in chemically disordered $Mn_{0.8}N_{0.2}$/CoFe systems — Simon Tilleke, •Katharina Fritz, Björn Büker, and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

In a recent publication [1], we reported on large exchange bias obtained in Ta/Θ-MnN/CoFe stacks at room temperature. In search for Mn-N phases with higher anisotropy energy, we investigated Mn-N films with lower nitrogen content to obtain other antiferromagnetic Mn-N phases, such as η-Mn_3N_2 or ζ-Mn_2N with the same deposition process.

We found an antiferromagnetic phase at the composition $Mn_{0.8}N_{0.2}$ that allows for large exchange bias with an interfacial exchange energy of $J_S = 0.39\,\mathrm{mJ/m^2}$ (similar to Θ-MnN/CoFe), but with a significantly reduced critical thickness of the antiferromagnet and thus a higher magnetocrystalline anisotropy energy. X-ray diffraction identifies the $Mn_{0.8}N_{0.2}$ as a simple, chemically disordered fcc structure with no traces of an ordered ϵ-Mn_4N structure in the as-deposited state. Annealing at temperatures above 150 °C will, however, induce chemical ordering of the Mn and N atoms and a transformation into well-ordered ϵ-Mn_4N is completed at annealing temperatures above 200 °C. After the transformation, no exchange bias is detected, in line with the ferrimagnetic ground state of the ϵ-Mn_4N phase. Exchange bias up to 1400 Oe is obtained at room temperature at a $Mn_{0.8}N_{0.2}$-thickness of 20 nm.

[1] M. Meinert *et al.*, Phys. Rev. B **92**, 144408 (2015)

MA 66.4 Fri 9:30 P2-OG2

Multifrequency ferromagnetic resonance study of the antiferromagnetic-ferromagnetic phase transition in FeRh — •Anna Semisalova[1,2], Jonathan Ehrler[1,3], Craig Barton[4], Thomas Thomson[4], Kilian Lenz[1], Jürgen Fassbender[1,3], Kay Potzger[1], and Jürgen Lindner[1] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]Lomonosov MSU, Faculty of Physics, Moscow, Russia — [3]Technische Universität Dresden, Dresden, Germany — [4]University of Manchester, School of Computer Science, Manchester, UK

The first order phase transition of an equiatomic FeRh thin film from the antiferromagnetic (AFM) to the ferromagnetic (FM) state was studied using broadband ferromagnetic resonance (FMR). The films were deposited on MgO(001) substrates by means of magnetron sputtering of an alloy target. The position and linewidth of the FMR signal have been investigated in the frequency range up to 50 GHz. Conclusions on the temperature dependence of the magnetic damping are presented. The linewidth was found to be strongly affected by the exchange coupling due to reversible nucleation of AFM and FM domains in FeRh within the temperature range of the phase transformation.

MA 66.5 Fri 9:30 P2-OG2

Optical detection of ferromagnetic resonance via photoluminescence in diamond NV-centers — Martin Wagener, •Chris Koerner, and Georg Woltersdorf — Martin-Luther-University Halle-Wittenberg, Institute of Physics, von-Danckelmann-Platz 3, 06120 Halle(Saale), Germany

We optically detect electron spin resonance in nanoscale diamonds with

NV-centers by photoluminescence measurements (ODMR). When the nano-diamonds are dispersed on top of an yttrium iron garnet (YIG) film the ferromagnetic resonance (FMR) of YIG becomes visible in the ODMR signal. This effect has previously been observed by Wolfe et al. [1,2]. Our work intends to unravel the physical origin of the cross coupling between FMR in YIG and the ODMR in the diamond NV-centers. In doing so we investigate the material dependence, the influence of spacer layers, and the frequency or field dependence of the coupling in the ODMR signal.

[1] C. S. Wolfe et al. Phys. Rev. B 89, 180406 (2014)
[2] C. S. Wolfe et al. ArXiv 1512.05418v2 (2016)

MA 66.6 Fri 9:30 P2-OG2

Coupling of magnetism and structural phase transition in V2O3/Co bilayers — •Changan Wang[1,2,3], Chi Xu[1,2], Ye Yuan[1,2], Yu-Jia Zeng[3], Manfred Helm[1,2], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstr. 400, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany — [3]Shenzhen Key Laboratory of Laser Engineering, College of Optoelectronic Engineering, Shenzhen University, 518060 Shenzhen, China

Exchange couplings across interfaces of hybrid magnetic heterostructures are being considered as unique opportunity for functional materials design. In this study, we show that both coercivity and magnetization of V2O3/Co bilayers are affected by the stress associated with structural phase transition across metal-insulator phase transition in V2O3. The change in coercivity is as large as 76% in a very narrow temperature range. The magnetic properties can be controlled by stress, which is significant for future multiferroic and spintronics applications.

MA 66.7 Fri 9:30 P2-OG2

Giant perpendicular exchange bias with antiferromagnetic MnN — •Philipp Zilske and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University

Exchange bias systems have been extensively investigated due to their technological applications in magnetic sensors based on magnetic tunnel junctions or spin valves. Recently, a new exchange bias system consisting of MnN/CoFe bilayers, which shows huge in-plane exchange bias up to 1800 Oe at room temperature, was discovered [1].

Here, we report on an out-of-plane exchange bias system that is also based on the antiferromagnet MnN. Ta/MnN/CoFeB/MgO stacks were grown on amorphous SiOx via reactive magnetron sputtering at room temperature. Diffraction measurements revealed a polycrystalline, columnar growth of the MnN in (001) direction. The dependence of the exchange bias field on the MnN and CoFeB thickness, as well as on the annealing temperature was investigated. This way, we achieved perpendicular exchange bias fields up to 3600 Oe with a coercive field around 350 Oe at room temperature. Furthermore, the anisotropy field was determined for the different stacks yielding values up to 3250 Oe. The perpendicular exchange bias reported here is larger than any previously reported value and possibly opens a route to magnetically stable, perpendicularly magnetized spin valves [2].

[1] M. Meinert et al., Phys. Rev. B **92**, 144408 (2015)
[2] J. Y. Chen et al., Appl. Phys. Lett. **104**, 152405 (2014)

MA 66.8 Fri 9:30 P2-OG2

Magnetic Force Microscopy studies of synthetic perpendicular anisotropy antiferromagnets modified by ion beam irradiation — •Fabian Samad[1], Benny Böhm[1], Leopold Koch[1,2], Fabian Ganss[1], Sri Sai Phani Kanth Arekapudi[1], Miriam Lenz[2], Sven Stienen[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany

By using ion beam irradiation of different energy and flux we modify and tune the magnetic reversal and microstructure in synthetic perpendicular anisotropy antiferromagnets consisting of [(Co/Pt)Co/Ru] multilayer systems. The magnetic energy balance between antiferromagnetic interlayer exchange and dipolar fields in the initial state of the samples has been tuned to have two local energy minima, one for laterally correlated and vertically anti-correlated magnetic structure (single domain antiferromagnet) and the other for laterally anticorrelated and vertically correlated magnetic structure (ferromagnetic stripe domains) [1]. Ion beam irradiation is then subsequently used to locally alter the magnetic microstructure from one state to the other to create laterally co-existing phases and study their reversal behavior in external magnetic fields using Magnetic Force Microscopy.

[1] O. Hellwig, J. B. Kortright, A. Berger and E. E. Fullerton, ”Magnetic Reversal in Antiferromagnetically Coupled Perpendicular Films”, J. Magn. Magn. Mater. 2007, 319, 13.

MA 66.9 Fri 9:30 P2-OG2

Impact of ion irradiation on magneto-resistance properties of synthetic antiferromagnets based on $[(Co/Pt)_{X-1}Co/Ru]_N$ multilayers — •Benny Böhm[1], Fabian Samad[1], Leopold Koch[1,2], Sri Sai Phani Kanth Arekapudi[1], Fabian Ganss[1], Miriam Lenz[2], Sven Stienen[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany

In this study integral magnetic properties and local microstructure in synthetic perpendicular anisotropy antiferromagnets consisting of $[(Co/Pt)_{X-1}Co/Ru]_N$ multilayers are modified using ion irradiation. The magnetic domain structure in the perpendicular anisotropy system is systematically modified by introducing antiferromagnetic exchange (via the Ru-thickness). This also results in two singular reversal modes (magnetic phases), one phase in which the AF exchange dominates (results in no magnetic stray field on the surface) and the other in which the dipolar interaction dominates leading to ferromagnetic stripe domains. Furthermore, ion irradiation with different kinetic energies and fluences is employed to locally modify the microstructure, therefore switching from one phase to another, resulting in laterally co-existing AF and FM-regions. Initial magneto-transport measurements on magnetic heterostructures will be presented.

[1] Olav Hellwig, Taryl L. Kirk, Jeffrey B. Kortright, Andreas Berger & Eric E. Fullerton, “A new phase diagram for layered antiferromagnetic films”, Nature Materials 2, 112 - 116 (2003)

MA 66.10 Fri 9:30 P2-OG2

Ion irradiation induced cobalt/cobaltoxide heterostructures: from materials to devices — •Donovan Hilliard[1,2], Oguz Yildirim[1], Ciarán Fowley[1], Sri Sai Phani Kanth Arekapudi[2], Marcin Perzanowski[3], Hamza Cansever[1,4], Lakshmi Ramasubramanian[1,2], Olav Hellwig[1,2], and Alina Deac[1] — [1]Helmholtz-Zentrum Dresden - Rossendorf — [2]Technische Universität Chemnitz — [3]Institute of Nuclear Physics PAN — [4]Technische Universität Dresden

Spintronic devices are often patterned from continuous films into micro- or nanostructures. Fabrication of those nano-devices is self-limited and depends on the lateral resolution of the chosen fabrication method. Ion irradiation offers an alternative route to introduce smaller magnetic patterns limited by the size of the ion beam. Irradiation of oxide materials can cause chemical reduction and lead to the local formation of metallic species. By using the oxide family of ferromagnets (e.g., Fe, Ni and Co), reduction leads to the formation of ferromagnetic and conducting volumes limited by the size of the ion irradiated area that are embedded into a non-magnetic and insulating matrix. On the other hand, the physical mechanism behind ion irradiation-induced oxide reduction could not be explained. Therefore, our studies focus on ion (H, He, Ne, O) irradiated cobalt-oxide (CoO or Co3O4) systems in order to explain the physics behind the process. Also, the knowledge is being exploited to tune exchange-bias direction, prepare nano contacts for synchronized spin torque oscillators, and to form topographically stabilized magnetic skyrmions.

MA 66.11 Fri 9:30 P2-OG2

Tunnel Junction Fabrication for Tunneling Anisotropic Magnetoresistance Spectroscopy — •Michaela Schleuder[1,3], Matthias Althammer[1,3], Matthias Pernpeintner[1], Hans Huebl[1,3,4], Daniel Meier[2], Günter Reiss[2], and Rudolf Gross[1,3,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Universität Bielefeld, Bielefeld, Germany — [3]Physik-Department, Technische Universität München, Garching, Germany — [4]Nanosystems Initiative Munich (NIM), Munich, Germany

Magnetic tunnel junctions (MTJs) consisting of one ferromagnetic metal electrode, an insulating barrier, and a normal metal counter electrode exhibit the so-called tunneling anisotropic magnetoresistance. Due to spin-orbit interaction, the resistance of the MTJ depends on the relative orientation of the magnetization with respect to the crystallographic axes of the ferromagnet. We discuss the fabrication strategies for MTJs based on the Heusler alloys Co_2FeAl and Co_2FeSi using MgO as the insulating barrier and Pt or Au as the counter electrode. The fabrication consists of a three-step electron lithography process, including subsequent Ar-ion etching and SiO_2 sputter deposition. We present optical micrographs and atomic force microscopy images of the optimized fabrication steps with junction sizes down to the nm regime, confirming the successful fabrication of MTJs.

We show first results on the electrical characterization of these MTJs. This optimized fabrication scheme paves the way for more complex device patterns.

MA 66.12 Fri 9:30 P2-OG2

Lattice effects accompanying the colossal magnetoresistance effect in $HgCr_2Se_4$ — •S. Hartmann[1], E. Gati[1], C. Lin[2], Y. Shi[2], Y. Li[2], J. Müller[1], and M. Lang[1] — [1]Physikalisches Institut, Goethe Universität, SFB/TR49, 60438 Frankfurt, 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 occurrence of electronic and magnetic phase separation in some of these materials has led researchers to suggest percolating magnetic polarons as one route for describing 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 magnetic polarons. 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 [2]. We will discuss the phenomenology of the coupling of charge and magnetic degrees of freedom to the lattice distortion and compare our results to other CMR materials. [1] Manna et al., PRL 2014; [2] Guan et al., PRL 2015

MA 66.13 Fri 9:30 P2-OG2

Single crystal growth and structure of $Li_2Fe_{1-x}Mn_xSiO_4$ — •Hagen Schray[1], Christoph Neef[1], Hubert Wadepohl[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institut für Physik, Universität Heidelberg, 69120 Heidelberg, Deutschland — [2]Anorganisch-Chemisches Institut, Universität Heidelberg, 69120 Heidelberg, Deutschland

$Li_2Fe_{1-x}Mn_xSiO_4$ single crystals were grown by means of the optical floating zone technique at elevated Ar-pressure of up to 50 bar. The growth parameters and in particular the effect of pressure are discussed with respect to Mn-doping and the oxygen stoichiometry of the system. The microstructure of the grown single crystals and crystallites was studied by EDX and electron microscopy. A mm^3 sized Li_2FeSiO_4 single crystal was successfully obtained which features the known high temperature structure with *Pnmb*-symmetry. Single crystal and powder XRD were applied to study the doping series $Li_2Fe_{1-x}Mn_xSiO_4$ and to refine the structure of the end member Li_2FeSiO_4 in detail. For this crystal, magnetic studies confirm high crystallinity showing up in a λ-type antiferromagnetic transition at $T_N = 17$ K and evidence for magnetic correlations up to $\leq$50 K.

MA 66.14 Fri 9:30 P2-OG2

Hall effect in $Fe_{3-x}Mn_xSi$ Heusler alloys — •Johannes Kroder, Gerhard Fecher, Guido Kreiner, and Claudia Felser — MPI CPfS, Dresden

The Hall effect occurs in all conducting materials when a magnetic field is applied perpendicular to the current. For ferromagnetic materials the effect may also be observed without applied field which is called anomalous Hall effect (AHE). Intrinsic and extrinsic contributions to the AHE can be distinguished. The intrinsic contribution is associated with the Berry curvature which is present in all ferromagnets. It is usually assumed that the AHE is not present in antiferromagnets because of the vanishing net magnetization. However, Chen *et al.* [1] pointed out that the AHE can also be observed in antiferromagnets with non-collinear spin structure due to a non vanishing Berry curvature. This was recently experimentally confirmed by Nayak *et al.* [2]. It is therefore interesting to investigate the well-known Heusler alloys $Fe_{3-x}Mn_xSi$ (0.75 < x < 1.75). These compounds show a transition from collinear to non-collinear ferrimagnetic order below 60 K accompanied with a change of the Berry curvature. We report on the series of polycrystalline $Fe_{3-x}Mn_xSi$ prepared by arc melting and characterized by temperature dependent Hall measurements.

[1] Chen *et al.*, PRL 112, 017205 (2014); [2] Nayak *et al.*, Sci. Adv., e1501870 (2016)

MA 66.15 Fri 9:30 P2-OG2

Isotropic, high coercive field in melt-spun tetragonal Heusler Mn_3Ge — •Adel Kalache[1], Susanne Selle[2], Guido Kreiner[1], Gerhard H. Fecher[1], Thomas Höche[2], and Claudia Felser[1] — [1]Max Planck Institut CPFS, Dresden, Germany — [2]Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Halle, Germany

Tetragonally distorted Heusler are known for their high crystalline anisotropy, tunable magnetization and high Curie temperature and therefore are candidates for rare-earth-free permanent magnets. We report on nanostructured Mn_3Ge ribbons with a composition ranging from 77 to 74 at.% Mn prepared using induction melting, melt-spinning and subsequent heat treatment. Obtained ribbons show hard magnetic properties due to the highly anisotropic tetragonal $D0_{22}$ structure of Mn_3Ge. Depending on the composition and the amount of ferrimagnetic Mn_5Ge_2 as a secondary phase, a coercivity of up to $\mu_0 H_C = 2.62$ T was obtained for the $Mn_{75}Ge_{25}$ composition. Microstructure investigations by transmission electron microscopy confirmed the formation of the secondary phase. All samples show isotropic coercive fields, i.e. independent of the direction of the applied magnetic field in contrast to already known epitaxial thin films. The Curie temperature was found to be higher than 800 K, which is the temperature of the phase transition from the tetragonal $D0_{22}$ structure to the hexagonal $D0_{19}$ structure. Despite its low magnetization, the large coercive field in Mn_3Ge represents an opportunity to study exchange-spring magnets consisting of soft and hard magnetic phases.

MA 66.16 Fri 9:30 P2-OG2

Critical thicknesses of magneto-electronic properties in $La_{0.7}Sr_{0.3}MnO_3$ — •M. Wilhelm[1], T. Gerber[1], P. Lömker[1], R. Heinen[1], F. Gunkel[2], R. Dittmann[6], A. Gloskovski[3], W. Drube[3], M. Gorgoi[4], and M. Müller[1,5] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institut, PGI-6 — [2]IWE2, RWTH Aachen University — [3]DESY Photon Science, Hamburg — [4]HZB, BESSY II, Berlin — [5]Fakultät für Physik, and CENIDE, Universität Duisburg-Essen — [6]Forschungszentrum Jülich GmbH, Peter Grünberg Institut, PGI-7

Transition metal oxides, like perovskite manganites, are extensively investigated due to their richness of underlying physics and potential technological applications. Special attention is paid to the half-metallic ferromagnetic oxide $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), due to its high spin polarization ($\sim$95 %) and the high Curie temperature (370K), which makes it a promising candidate for room temperature spintronic applications. We have investigated the structural, magnetic and electronic properties of heteroepitaxially grown $La_{0.7}Sr_{0.3}MnO_3$ thin films on a $SrTiO_3$ (001) substrate by means of XRD, VSM and HAXPES, respectively. In particular, we have performed a detailed study on the thickness-property relationship, in which the LSMO film thickness was gradually reduced from 20 nm (bulk) down to the ultra-thin film regime of 0.8 nm. We observe a critical thickness between 0.8 - 1.2 nm, which is completely nonferromagnetic as well as nonmetallic. Further, we have estimated a metal-insulator transition occurring at $\sim$3 nm.

MA 66.17 Fri 9:30 P2-OG2

Growth, Structure, and Properties of La2BIrO6 (B = Co, Mg, Zn) Double Perovskite Single Crystals — •Ryan Morrow[1], Mihai Sturza[1], Anja Wolter-Giraud[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]Leibniz Institute for Solid State and Materials Research Dresden IFW, Dresden, Germany — [2]Institute for Solid State Physics, Technische Universität Dresden, Dresden, Germany

Double perovskites have received a great deal of attention in recent times due to their magnetic properties. However, the vast majority of experimental data thus far in this field has been generated with powder samples resulting in numerous open questions concerning the underlying principles governing the magnetic properties of these complex oxides. Here it is shown that, using a flux method, double perovskite iridate single crystals as large as 3 mm with formula La2BIrO6 (B = Co, Mg, Zn) have been grown. The structure and properties of the crystals are characterized and are in agreement with previous powder data. Therefore, future more detailed experiments will be possible.

MA 66.18 Fri 9:30 P2-OG2

In-Operando Studies of Ultrathin Magnetic Oxides: $NiFe_2O_4$ and $La_{0.7}Sr_{0.3}MnO_3$ — •Ronja Anika Heinen[1], Marek Wilhelm[1], Patrick Lömker[1], Katrin Neureiter[1], Timm Gerber[1], Andrei Gloskovskii[2], Wolfgang Drube[2], and Martina Müller[1] — [1]Forschungszentrum Jülich GmbH, PGI-6, Jülich, Germany — [2]Deutsches Elektronen-Synchrotron Desy, Hamburg, Germany

Transition metal (TM) oxides exhibit a variety of physical properties due to their high tunability of spin, orbital and charge degrees of freedom. The initial way to tailor these properties is a precisely controlled growth process in order to prepare single-crystalline thin films. In the next step, electric or magnetic fields can be applied in order to tune and probe the magnetic and electric response and chemical compositions.

In our experiments, we investigate ultrathin films of the transition metal ferro(i)magnetic oxides $NiFe_2O_4$ (NFO) and $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) on $SrTiO_3(001)$ substrates. We use in-operando HAXPES with excitation energies of $E = 4000 - 6000$ eV and apply bias voltages of $U = \pm 3\,V$ in order to analyse the electronic shifts of the chemical fingerprint of NFO and LSMO heterostructures. Furthermore, the ultra thin films are characterised in terms of electrical properties under applied in-plane and out-of-plane magnetic field. Also the magnetic response, i.e. the coercive field and saturation magnetization, are measured under applied electrical field via SQUID. The results provide insight into the interfacial band arrangement and chemical distribution of ultrathin 3d TM magnetic oxides.

MA 66.19 Fri 9:30 P2-OG2

Novel materials for antiferromagnetic spintronics — Jan Balluff, •Kevin Diekmann, Markus Meinert, and Günter Reiss — Bielefeld University

Antiferromagnetic spintronic devices often rely on antiferromagnets with large spin-orbit coupling and require a Néel temperature well above 300 K for room temperature operation. Currently, there is only a limited number of materials available that fulfill these criteria, such as PtMn, Ir_xMn_{1-x}, FeRh and a few others. These materials have in common that they contain a noble metal to some extent, which is obviously undesirable for a large-scale application of these materials due to the low availability and therefore high price.

Here we present an effort to identify novel antiferromagnetic Heusler compounds with high Néel temperature. We use high-throughput ab initio calculations to find stable phases and perform additional DFT calculations to identify the magnetic ground state and to determine the critical temperature. Overall, 69 Heusler compounds are identified as antiferromagnetic, of which 20 compounds are predicted to have $T_N > 290$ K. The method is applicable to arbitrary structure types and is not limited to Heusler compounds.

MA 66.20 Fri 9:30 P2-OG2

Study of spin reorientation in $NdFe_{0.5}Mn_{0.5}O_3$ — Ankita Singh[1], Avijeet Ray[1], Anil Kumar Jain[2], Padmanabhan Balasubramanian[1], Tulika Maitra[1], and •Vivek Kumar Malik[1] — [1]Department of Physics, Indian Institute of Technology Roorkee, Roorkee 247 667, India — [2]Solid State Physics Division, Bhabha Atomic Research Center, Mumbai, 400 085, India

The structural, magnetic, and electronic properties of $NdFe_{0.5}Mn_{0.5}O_3$ have been studied in detail using bulk magnetization, neutron/x-ray diffraction and first principle density functional theory. The material crystallizes in the orthorhombic *Pbnm* structure, where both Mn and Fe occupy the same crystallographic site (4*b*). Mn/Fe sublattice of the compound orders in to a G-type antiferromagnetic phase close to 250 K. The magnetic structure belongs to Γ_1 irreducible representation with spins aligned along the crystallographic *b* direction which is highly unusual, since most of the orthoferrites and orthochromites order in the Γ_4 representation below the Néel temperature. Below 70 K, the magnetic structure coexists as a sum of two irreducible representations ($\Gamma_1+\Gamma_2$) as seen from neutron diffraction. At 6 K, the magnetic structure belongs entirely to Γ_2 representation with spins aligned antiferromagnetically along the crystallographic *c* direction having a small ferromagnetic component (F_x). The unusual spin reorientation and correlation between magnetic ground state and electronic properties have been investigated using first principle calculations in the GGA+U+SO formalism.

MA 66.21 Fri 9:30 P2-OG2

Comparative study of CoFeAlB and CoFeB FMR properties for spin torque devices — •Andres Conca[1], Thomas Meyer[1], Takafumi Nakano[2], Yasuo Ando[2], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Department of Applied Physics, Tohoku University, Japan

The magnitude of critical current required for switching in spin transfer torque (STT) devices is ruled by the product of the Gilbert damping parameter α and the square of the saturation magnetization M_s of the electrode material. $Co_{40}Fe_{40}B_{20}$ is dominantly used as free layer electrode in MgO-based MTJs. The material has a low α around 0.0042 but the large M_s hinders the use in STT devices. In this sense, research has been carried out to dope CoFeB alloys in order to reduce the magnetization without destroying the low damping properties. Here, we present results of the FMR properties of film series of $Co_{36}Fe_{36}Al_{18}B_{10}$ with different annealing temperatures. The dependence of the linewidth, α, and M_s have been obtained. Additional information regarding the exchange constant is gained through measurements of the perpendicular standing spin waves (PSSW). An additional CoFeB series has also been measured for comparison. The data proves a significant reduction of M_s and the exchange constant in CoFeAlB compared to CoFeB while α remains similar or even smaller for most of the annealing temperatures. The evolution of α with annealing shows a different behavior for both materials. This proves the suitability of CoFeAlB for STT devices. Support by M-era.Net and HEUMEM is acknowledged.

MA 66.22 Fri 9:30 P2-OG2

Inertia effects in the real-time dynamics of a quantum spin coupled to a Fermi sea — •Mohammad Sayad, Roman Rausch, and Michael Potthoff — I. Institut für Theoretische Physik, Universität Hamburg

Inertia effects in spin dynamics have been discussed intensively in the recent years by means of LLG-type approaches for classical spins only. However, in case of a quantum spin, inertia effects have not yet been studied. As compared to spin precession and damping, nutation is a higher-order effect, thus it is not a priori clear whether or not spin nutation is suppressed by quantum fluctuations. In order to clarify this issue, we consider the Kondo impurity model and study the spin dynamics, initiated by switching the direction of a magnetic field, by means of the time-dependent density-matrix renormalization group. We identify quantum effects by a systematic comparison of the spin dynamics for different spin quantum numbers S with the tight-binding spin-dynamics theory for the classical-spin Kondo model. We find a qualitative and with increasing spin-quantum numbers also quantitative agreement between quantum and semiclassical dynamics. The quantum-spin dynamics, however, exhibits a rapid damping of the nutational motion. Apart from the longitudinal spin dynamics reflecting the time-dependent Kondo effect, nutational damping is essentially the only characteristics of the quantum nature of the spin occurs on femtosecond-time scale and is basically independent of the relaxation time scale for the precessional motion.

M. Sayad et al., Europhys. Lett. 116, 17001 (2016)

MA 66.23 Fri 9:30 P2-OG2

Ultrafast spin dynamics in CoFeB/MgO/CoFeB magnetic tunnel junctions — Leon Duschek, •Jakob Walowski, Christian Denker, Ulrike Martens, and Markus Münzenberg — Ernst-Moritz-Arndt Universität, Greifswald

Magnetization dynamics in CoFeB layers with out-of-plane magnetic anisotropy (PMA) separated by a crystalline MgO isolating layer are probed in all-optical pump-probe experiments.

In 2013 He et al. [1] have shown, that the laser excitation in such layer systems can induce an exchange of spins through the MgO barrier. Extending those measurements to samples with patterned circular structures with diameters from $1\,\mu m$ to $5\,\mu m$ enables the observation of both processes in individual MTJs. Due to the small sizes and a crystalline structure, the exchange of spins through the MgO barrier takes place by coherent tunneling. The investigated magnetic layers have thicknesses from $0.9\,\mu m$ to $1.3\,\mu m$, to ensure PMA. The dynamics are probed using both, the Kerr rotation and ellipticity. Because the stacks are thinner than the penetration depth of the laser light, each component provides the information at different depths of the layer stack [2]. Thus we observe the dynamics from both magnetic layers individually, gaining insight into the processes inside, which stem from spin-flip scattering and from spin-polarized transport. Both, the spin dynamics and the spin transport depend on the properties of the magnetic electrodes and the tunnel barrier.

[1] W. He et al., Scientific Reports 3, 2883 (2013)

[2] J. Wieczorek et al., PRB 92, 174410 (2015)

MA 66.24 Fri 9:30 P2-OG2

Ultrafast Magnetization Dynamics in $[FePt]_{1-\chi}$ Mn_χ — •Cinja Seick[1], Ute Bierbrauer[2], Nataliia Safonova[3], Benjamin Stadtmüller[2], Manfred Albrecht[3], Martin Aeschlimann[2], Daniel Steil[1], and Stefan Mathias[1] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [3]Institute of Physics, University of Augsburg, Germany

We study the magnetization dynamics of $[FePt]_{1-\chi}$ Mn_χ in order to investigate the influence of adding Mn to the ferromagnetic compound FePt, which is relevant for technological applications(1) and basic research(2). In our TR-MOKE studies on $[FePt]_{1-\chi}$ Mn_χ, we found a drastic decrease of the demagnetization time in comparison to pure FePt(3). Furthermore, we compare fluence-dependent measurements of the system to the predictions of the M3TM and find a sudden decrease in the demagnetization time at medium demagnetization strength, which is not present for pure FePt. This two differences seem to be caused by the added Mn.

References:

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(2) C-H. Lambert et all., Science **345**, 1337-1340 (2014)
(3) S. Iihama et al., J. Phys. D: Appl. Phys. **49**, 035002 (2016)

MA 66.25 Fri 9:30 P2-OG2

Generation of ultrashort current pulses by the inverse spin Hall effect — •Jonathan Weber and Georg Woltersdorf — Martin Luther Universität Halle-Wittenberg

We use optical pump pulses to generate current pulses using the spin-dependent Seebeck effect and the inverse spin Hall effect (ISHE) in normal metal/ferromagnet bilayers. For this the bilayer structures are used to terminate a coplanar waveguide. The optical excitation from an ultrafast amplified laser system injects an ultrashort spin current pulse into the ferromagnetic layer via the spin-dependent Seebeck effect [1]. Subsequently, this spin current pulse is converted into a charge current pulse inside the normal metal layer via the ISHE. The electric signal that is generated by the ISHE is recorded by a fast sampling oscilloscope with a bandwidth of approximately 50 ps. Based on other experiments we expect an actual pulse length of only a few hundred femtoseconds [1, 2]. By normalizing the ISHE signals to the pump pulse energy we find an optical pulse to THz pulse conversion efficiency that is comparable to the tilted pulse front approach [3].

[1] A. Melnikov. et. al.: arXiv:1606.03614[physics.optics] (2016)
[2] T. Seifert, T. Kampfrath, et. al.: doi:10.1038/nphoton.2016.91
[3] H. Hirori, et.al.: Appl. Phys. Lett. 98, 091106 (2011)

MA 66.26 Fri 9:30 P2-OG2

Temperature dependence of Current-Induced-Domain-Wall-Motion — •Tianping Ma[1], Robin Bläsing[1], Chirag Garg[1,2], Tom Lichtenberg[1], See-Hun Yang[2], and Stuart Parkin[1,2] — [1]Max Planck Institute for Microstructure Physics, Halle (Saale), D06120, Germany — [2]IBM Almaden Research Center, 650 Harry Road, San Jose, California 95120, USA

Racetrack memory, which uses current to control the motion of magnetic domain walls, is one of the most promising next generation memory devices. Using a combination of four spin-orbit-coupling derived phenomena, namely, perpendicular magnetic anisotropy (PMA), the Spin Hall Effect (SHE), the Dzyaloshinskii-Moriya exchange Interaction(DMI) and a synthetic antiferromagnetic (SAF) structure, Current-Induced-Domain-Wall-Motion (CIDWM) velocities can reach more than ~1,000 m/s. However, temperature, as another important parameter which will influence the CIDWM behaviour, has not yet been deeply investigated. As temperature changes, many physical parameters will change and thereby influence the CIDWM. Moreover, temperature will likely greatly influence any pinning of the domain walls: thermal fluctuations will likely affect the CIDWM threshold current intensity. Here in this work, we have performed CIDWM measurements over a wide range of temperature (80K to 440K). We observe a pronounced temperature dependence of the domain-wall motion velocity, the threshold current intensity and the SHE induced spin current injection efficiency. These measurements help us to gain a better understanding of the physics behind CIDWM.

MA 66.27 Fri 9:30 P2-OG2

Control of the magnetization dynamics through the Magneto-Elastic coupling effect — •Simone Finizio[1], Sebastian Wintz[1,2], Eugenie Kirk[1], Anna Suszka[1], Sebastian Gliga[3], and Jörg Raabe[1] — [1]Paul Scherrer Institut, Villigen PSI, Switzerland — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]University of Glasgow, Glasgow, UK

The magnetoelastic (ME) coupling has recently become of interest thanks to its numerous applications, e.g. in the fabrication of magnetoelectric multiferroics. This effect has been recently studied quasi-statically on micro- and nanostructured magnetostrictive materials strained using piezoelectric substrates. However, due to limitations in the radio frequency (RF) properties of piezoelectric materials, the influence of the ME coupling on the magneto-dynamical processes has not yet been investigated in depth. Here, thanks to a newly-developed approach that allows the in-situ straining of magnetostrictive materials whilst preserving good RF properties of the substrate, we present a first study of the influence of the ME coupling on the gyration dynamics of magnetic vortices in microstructured magnetostrictive elements using time-resolved x-ray magnetic microscopy. In particular, we observe that the application of a strain to the magnetostrictive material leads to a reduction of the gyration eigenfrequency, and to a modification of the orbit of the vortex core, both of which can be controlled by changing the magnitude of the applied strain.

MA 67: Poster 4

Time: Friday 9:30–13:00 Location: P2-OG3

MA 67.1 Fri 9:30 P2-OG3

Microwave excitation and optical detection of spin wave beams in NiFe films — •Helmut Körner, Johannes Stigloher, and Christian Back — Institut für Experimentelle und Angewandte Physik, Uni Regensburg, Germany

Only recently, Gruszecki et al. [1] presented an approach enabling the generation of narrow spin wave (SW) beams in thin homogenous nano-sized ferromagnetic films by microwave current. Using micromagnetic simulations they showed that the desired beam-type behaviour can be achieved with the aid of a properly designed coplanar waveguide transducer generating a non-uniform microwave magnetic field. The resulting SW beams propagate over distances of several micrometers. Moreover, they state that their approach can be generalized to different magnetization configurations, e.g. forward-volume or Damon-Eshbach (DE) geometry, respectively, and yield multiple SW beams of different width at the same frequency.

Here, we present the results of an experimental study on SW beams propagating in the DE geometry in a 50 nm thick NiFe film by imaging these beams using time-resolved scanning Kerr microscopy (TR-MOKE). We show that it is possible to excite and image (multiple) SWs beams of varying width at the same frequency by carefully tuning the amplitude of the externally applied magnetic field. The shape of the SW beams is inherently determined by the anisotropic nature of the DE SW dispersion for small wave numbers and is also affected by the shape of the coplanar waveguide.

[1] P. Gruszecki et. al., Sci. Rep. 6, 22367 (2016)

MA 67.2 Fri 9:30 P2-OG3

Realization of a macroscopic spin-wave majority gate and its miniaturisation — •Martin Kewenig[1], Tobias Fischer[1,2], Dmytro A Bozhko[1], Ihor I Syvorotka[3], Carsten Dubs[4], Philipp Pirro[1], Burkard Hillebrands[1], and Andrii Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]MAINZ Graduate School of Excellence - Materials Science in Mainz, Mainz, Germany — [3]Department of Crystal Physics and Technology, Scientific Research Company Carat, Lviv, Ukraine — [4]INNOVENT e.V. Technologieentwicklung Jena, 07745 Jena, Germany

Spin-wave logic devices offer large advantages compared to modern CMOS-based elements. An example for such a logic element is the majority gate. In this contribution, we present the investigation of a macroscopic spin-wave majority gate device made from a YIG film. We examine the spin-wave propagation by means of microwave techniques. The operation of the device as a majority gate was proven - the output phase of the signal was defined by the majority of the input phases. Additional time-resolved measurements have shown that the device can switch logic output within approximately 11 ns. In order to scale down spin-wave majority devices we fabricate microstructured combiner structures made from a 100 nm thick YIG film and examine the spin-wave transmission and reflection of different combiner structures by using Brillouin light scattering microscopy. This research has been supported by: EU-FET Grant InSpin 612759, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1).

MA 67.3 Fri 9:30 P2-OG3

Spatial resolved mapping of spin-wave modes in YIG film excited by an antenna — •Rouven Dreyer, Niklas Liebing, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Halle(Saale), Germany

Spin-wave propagation in magnetic materials may in the future allow to transmit and process information in an energy-efficient manner. Yttrium Iron Garnet (YIG) is one of the most interesting materials for spin wave based microwave devices due to its low Gilbert damping parameter and the correspondingly large spin wave propagation length. Phase resolved imaging of spin wave excitations is possible by time resolved Kerr microscopy. Here, we present the imaging of Damon-Eshbach and backward volume spin-wave modes in a 200 nm YIG film. Our experiments allow to determine the spin-wave dispersion for different configurations of in-plane wave vector and magnetization. Different antenna structures for spin-wave excitations are investigated.

MA 67.4 Fri 9:30 P2-OG3

Spin Wave Phase Shift upon Reflection — •Johannes Stigloher[1], Takuya Taniguchi[2], Martin Decker[1], Helmut S. Körner[1], Takahiro Moriyama[2], Teruo Ono[2], and Christian H. Back[1] — [1]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

In the experiments presented here, our main observation is a phase shift between incoming and reflected spin waves at an interface between a Permalloy film and a dielectric. Plane spin waves in the dipolar regime are excited by a microwave antenna. By design, the spin waves hit the edge of the film at an angle. An external field is used to tune the wave vector amplitude. It is applied in-plane and aligned parallel to the interface in order to avoid static demagnetizing effects. We detect spin waves by means of a time-resolved scanning Kerr microscope that allows us to directly image the wave fronts [1]. By fitting the interference pattern of incoming and reflected waves, we are able to extract the phase shift in real space. The origin of this shift can be attributed either to an effect similar to the Goos-Hänchen shift in optics or to a finite time delay between the waves. The effect might be used to characterize the interface [2].

[1] J. Stigloher et al. Physical Review Letters, 117, 037204 (2016)
[2] Yu. S. Dadoenkova et al. Applied Physics Letters, 101, 042404 (2012)

MA 67.5 Fri 9:30 P2-OG3

Nanotubes, a novel layout for magnonic applications. — •Jorge A. Otálora[1], Jürgen Lindner[2], Kornelius Nielsch[3], Pedro Landeros[4], and Attila Kákay[3] — [1]Departamento de Física, CEDENNA, Universidad Santiago de Chile, USACH, 9170124 Santiago, Chile — [2]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institute of Metallic Materials at the Leibniz Institute for Solid State and Materials Research, IFW, 01069 Dresden, Germany — [4]Departamento de Física, Universidad Técnica Federico Santa María, Avenida España 1680, Casilla 110-V, Valparaíso, Chile

The knowledge of mechanisms and architectures for controlling spin waves in ferromagnetic systems can be exploited within novel electronic devices. In this context, magnonic devices are proposed in the fields of signal processing, data computation as well as information transfer. In this work we propose a novel system that will significantly foster the endeavor, namely magnetic nanotubes. Here, we highlight their tunable and non-reciprocal spin wave properties. Their curvature-induced non-reciprocity is significant and is present not only in the SWs dispersion, but also manifests itself via a wavevector-dependent absorption leading to the difference in the extinction length of counter-propagating SWs along the tube length[1]. The non-reciprocity can be controlled with application of weak DC external magnetic fields along the tube's large axis. Our findings suggest that magnetic nanotubes can be exploited as a novel layout for flexible and reconfigurable magnonic circuits.[1]J.A. Otálora, et. al., Phys. Rev. Lett. 117, 227203 (2016)

MA 67.6 Fri 9:30 P2-OG3

The Transition from a Thin Film to a Full Magnonic Crystal and the Role of the Demagnetizing Field — •Manuel Langer[1,2], Falk Röder[1,2,3], Rodolfo A. Gallardo[4], Tobias Schneider[1,5], Sven Stienen[1], Christophe Gatel[3], René Hübner[1], Kilian Lenz[1], Jürgen Lindner[1], Pedro Landeros[4], and Jürgen Fassbender[1] — [1]HZDR, Dresden — [2]TU Dresden, Dresden — [3]CEMES-CNRS, Toulouse, France — [4]USM, Valparaíso, Chile — [5]TU Chemnitz, Chemnitz

The transition from a film to a full magnonic crystal is studied by sequentially ion-milling a 40 nm Ni80Fe20 film. The spin-wave resonances of each stage are detected by ferromagnetic resonance for both in-plain field main axes. Theoretical calculations and micromagnetic simulations yield the individual mode profiles, which are analyzed in order to track changes of the mode character. The latter is strongly linked to the evolution of the internal demagnetizing field. It's role is further studied by electron holography measurements of a hybrid magnonic crystal with 10 nm deep surface modulation. The complex effects of mode coupling, mode localization and anisotropy-like contributions by the internal field are unraveled. Simple transition rules from the nth film mode to the mth mode of the full magnonic crystal are formulated.

MA 67.7 Fri 9:30 P2-OG3

Non-reciprocal spin-wave edge modes — •Philipp Pirro, Qi Wang, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Non-reciprocal spin waves modes like the magneto-static surface wave (aka Damon-Eshbach mode) are well known phenomena based on the structure of the magnetic dipol-dipol interaction. By micromagnetic simulations, we show how these modes can be used to construct out-of-plane magnetized magnonic systems with chiral edge modes. By introducing defects in our structures, we investigate the protection of these unidirectional modes against back scattering. Interestingly, the exchange interaction has an important effect on the scattering characteristics since it influences the profiles and the frequency spacing of the individual modes. Based on these findings, we design non-reciprocal spin-wave elements which can be used in future magnonic logic elements as spin-wave isolators or circulators.

MA 67.8 Fri 9:30 P2-OG3

Non-Linear Spin-Wave Dynamics in Magnetic Vorticies — •Kai Wagner[1,2], Franziska Wehrmann[2], Friedrich Zahn[2], Attila Kákay[1], and Helmut Schultheiss[1,2] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]TU Dresden, D-01062 Dresden, Germany

Non-linear magnetisation dynamics in micron sized Permalloy disks in the vortex state are investigated by Brillouin-Light-Scattering Microscopy and micromagnetics. To study the spectral, temporal and spatial spin-wave dynamics, a homogeneous and continuous out-of-plane pumping field is applied. For low pumping powers we observe discrete radial modes, as expected for the linear regime and homogeneity of the pumping field. However, high pumping powers lead to multiple magnon scattering, as also observed in [1] for stripe geometries. This results in complex spectra with a multitude of simultaneously occurring power dependent spin-wave frequencies, which are different from the excitation frequency. This can not be explained by simple transition rules known for spin waves in thin films. Under high pumping powers the spin-wave spectra of the vortex state in micron disks appear to be nearly continous. Hence, the conservation of energy can be easily satisfied. Therefore we believe, the corresponding rules for momentum and angular momentum conservation in these scattering processes impose sharp power dependent constraints on the possible scattering processes. [1] R. E. Camley, Phys. Rev. B **89**, 214402 (2014)

MA 67.9 Fri 9:30 P2-OG3

Spin waves in magnetic films driven by optical pulses at high repetition rates — •Manuel Jäckl[1], Vladimir I. Belotelov[2,3], Ilya A. Akimov[1,4], Igor V. Savochkin[2], Dmitri R. Yakovlev[1,4], Anatoly K. Zvezdin[3,5], and Manfred Bayer[1,4] — [1]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany — [2]Lomonosov Moscow State University, 119991 Moscow, Russia — [3]Russian Quantum Center, Skolkovo, 143025 Moscow, Russia — [4]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [5]Moscow Institute of Physics and Technology, Moscow Region 141700, Russia

We excite magnetization precession in bismuth-substituted iron garnet (BIG) films by a train of circularly polarized fs-laser pulses with a high repetition rate of 1 GHz which is faster than the decay rate of the oscillation. This periodic pumping establishes a quasi-stationary source of spin waves (SW), namely a coherent magnon cloud from which SWs are emitted. With this approach we generate spectrally narrow SWs, so they can propagate over long distances, traceble up to almost 100 μm, propagating with a pronounced directionally. Furthermore we can increase the amplitude by an enhancement factor of up to one order of magnitude by synchronizing its frequency with the pulse repetition rate.

MA 67.10 Fri 9:30 P2-OG3

Imaging of conversion between different spin wave modes in thermal landscapes with micro-structured induction loops — •Rick Assmann[1], Marc Vogel[1], Andrii V. Chumak[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Fraunhofer-Institute for Physical Measurement Techniques IPM, Fraunhofer-Platz 1, 67663 Kaiserslautern, Germany

Spin wave propagation in thin ferrimagnetic films (YIG) can be described as wave propagation, following in most cases the well-known laws of optical propagation, e. g., Snell's law of refraction [Phys. Rev. Lett. 117, 037204 (2016)]. In contrast to optical materials, the dispersion relation of spin waves strongly depends on the direction of the external magnetic field. For in-plane magnetization backward volume magnetostatic spin waves (BVMSW) as well as magnetostatic surface spin waves (MSSW) can be excited, although situated at different frequency regions. A specially designed coplanar waveguide allows to excite spin wave beams [Sci. Rep. 6, 22367 (2016)]. Inducing a beamsplitter via thermal landscapes [Nature Physics 11, 487 (2015)] leads to a redirection of the beam and, hence, to a conversion from BVMSW to MSSW. This conversion and propagation can be observed with microstructured induction loops, which are scanned over the sample. We compare our experimental results with micromagnetic simulations.

Financial support by DFG collaborative research center SFB/TRR 173 "Spin+X" (project B04) is gratefully acknowledged.

MA 67.11 Fri 9:30 P2-OG3

Magnetic domains in FePt thin films for magneto-ionic effects — •Jonas Zehner[1], Sebastian Fähler[1], Rudolf Schäfer[1], Christine Damm[1], Liu Yang[1,2], Kornelius Nielsch[1], and Karin Leistner[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Deutschland — [2]Technische Universität Dresden, Deutschland

The manipulation of the magnetic properties by an external electric instead of magnetic field is highly interesting from a fundamental and technological point of view. Recently, large reversible voltage-induced changes of interfacial magnetism have been achieved by exploiting electrochemical reactions and denominated magneto-ionic effect [1, 2]. These results indicate that magneto-ionic changes of the magnetic microstructure are possible.

We investigate FePt thin films with regard to the evolution of a magnetic microstructure suitable for the observation of magneto-ionic effects. FePt films (4 nm) were pulsed laser deposited and L10 ordering achieved. Magnetic domain observation by Kerr microscopy revealed two fundamentally different domain characteristics. Large non equilibrium domains are observed in FePt films with increased anisotropy. In contrast, stable bubble like domains are found in the films with lower anisotropy.

First approaches towards electrochemical in situ Kerr microscopy were achieved on FePt thin films. Results showed electrochemical functionality and the possibility of magnetic domain observation through a transparent counter electrode and an electrolyte.

MA 67.12 Fri 9:30 P2-OG3

Structural and Magnetic Properties of FePt-Mn Thin Films — •Matthias Riepp[1], Nataliia Safonova[2], and Manfred Albrecht[2] — [1]Deutsches Elektronen Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany — [2]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany

Systematic investigations of the influence of Mn on the L_10 - phase formation, texture and magnetic properties of tri-layered FePt/Mn/FePt thin films were conducted. The layered films were magnetron sputtered on thermally oxidized Si substrates at room temperature and post annealed via rapid thermal annealing at temperatures ranging from 650° C - 800° C for 30 s in N_2 atmosphere. Pronounced formation of L_10 (001)-textured grains with large perpendicular magnetic anisotropy was observed for Mn concenrations up to 10 at. % particularly at annealing temperatures above 750° C. Only for Mn concentration of 20 at. % a slight reduction of the saturation magnetization and enhanced coercivity were observed.

MA 67.13 Fri 9:30 P2-OG3

Magneto-optic investigation of spin-orbit torques in metallic bilayers — •Robert Islinger, Martin Decker, Johannes Stiglohér, Martin Buchner, and Christian Back — Universität Regensburg, Deutschland

We study the spin-orbit torque (SOT) generated when applying a current to micrometer-sized ferromagnetic metal/heavy metal (FM/HM) stripes. We use the magneto-optic Kerr effect in a static experiment. A polarized laser beam is used to probe the out-of-plane component of the magnetization while scanning across the sample [1]. When applying an alternating current to the stripe, the equilibrium position of the magnetization changes which we detect magneto-optically. The field generated by the SO-interaction switches sign when inverting the equilibrium direction of the magnetization using an externally applied magnetic field while the contribution from the current induced Oersted field remains unchanged. Subtracting the detected voltage signals give access to the magnitude of the SOT. The material-related SOT coefficient beta can be derived and is compared for different FM/HM systems. Temperature dependent measurements down to 10K are performed to provide an insight into the temperature behavior of the SOTs. [1] Fan et al. Quantifying interface and bulk contributions to spin-orbit torque in magnetic bilayers, Nat.Comm 5, 3042 (2014)

MA 67.14 Fri 9:30 P2-OG3

Spin Hall effect in topological crystalline insulators Pb1-xSnxTe — •Jue Huang[1], Kai Chang[1,2], and Stuart Parkin[1] — [1]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany — [2]Department of Physics, Tsinghua University, 100084 Beijing, China

The development of spintronics devices currently drives much interest for the widespread applications in memory and logic devices. Therefore, it requires to search materials which can provide more efficient magnetization manipulation. Besides heavy-metal/ferromagnet bilayer materials, topological insulator bismuth selenide (Bi2Se3) is also reported to have large spin torque ratio [1]. We propose that the topological crystalline insulators (TCI) Pb1-xSnxTe, in which the surface exhibits even number of Dirac cone states and topologically protected by crystal symmetry, are potential candidates for spintronics technology. By growing (001) and (111) Pb1-xSnxTe thin films with molecular beam epitaxy (MBE) and measuring spin torque ferromagnetic resonance (ST-FMR) of these thin films, we study the spin Hall effect.

[1] Mellnik A. R., Lee J. S., et al., Nature 511, 449-451, 2014.

MA 67.15 Fri 9:30 P2-OG3

Interface optimization for spin Hall magnetoresistance experiments — •Saki Matsuura[1,2], Matthias Althammer[1,2], Stephan Geprägs[1], Hans Huebl[1,2,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems InitiativeMunich (NIM), München, Germany

The concept of pure spin currents, i.e. the net flow of spin angular momentum without an accompanying charge current, triggered the discovery of interesting new effects. Among these the spin Hall magnetoresistance (SMR) is present in ferromagnetic insulator (FMI) and normal metal (NM) bilayers, originating from the combined action of spin Hall and inverse spin Hall effect in the NM. The experimental fingerprint of the SMR is a characteristic dependence of the NM's resistivity on the magnetization orientation of the FMI. The SMR magnitude crucially depends on the transfer of a pure spin current accross the FMI/NM interface. We here systematically investigate the SMR in yttrium iron garnet (YIG)/Pt heterostructures, prepared by ex-situ and in-situ methods. To this end, we carried out angle-dependent magnetoresistance measurements and analyzed the SMR as a function of temperature and magnetic field strength. Our results show that for a sizeable SMR in ex-situ samples a suitable cleaning process of the YIG surface prior to the deposition of the Pt is crucial.

MA 67.16 Fri 9:30 P2-OG3

Growth, structural characterisation and magnetotransport measurements in Mn_3Ir thin-films — •James M Taylor[1,2], Edouard Lesne[1], Fasil Kidane Dejene[1], Claudia Felser[2], and Stuart S P Parkin[1] — [1]Max Planck Institute for Microstructure Physics, D-06120 Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Mn_3Ir antiferromagnetic thin-films, previously utilized to exchange pin ferromagnetic layers in spin valve devices, have recently attracted renewed attention for applications in spintronic devices due to theoretical predictions of a large Berry curvature driven anomalous Hall effect and the observation of a facet-dependent spin Hall effect. Large spin Hall angles of up to $\theta_{SH} = 0.2$ have been measured. Here we report the growth of highly-textured thin-films of Mn_3Ir and their structural characterisation. Techniques such as X-ray diffraction and atomic force microscopy demonstrate films grown in both (001) and (111) orientations with roughnesses of less than 1nm. Antiferromagnetic properties of the films were studied using SQUID magnetometry and X-ray magnetic circular dichroism, as well as exchange biasing to adjacent NiFe ferromagnetic layers. Large values of exchange bias field were obtained, up to $H_{Ex} = 306$ Oe, demonstrating the antiferromagnetic quality of the films. We extended our investigation to study electrical transport in lithographically patterned Mn_3Ir thin-films, including magnetotransport and microwave-frequency measurements.

MA 67.17 Fri 9:30 P2-OG3

Auto-oscillations in double constriction Spin-Hall nano-oscillators — •Toni Hache[1], Kai Wagner[1,2], Sri Sai Phani Kanth Arekapudi[1,3], Tobias Hula[1], Olav Hellwig[1,3], Jürgen Lindner[1], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung — [2]Technische Universität Dresden — [3]Technische Universität Chemnitz

Spin-Hall nano-oscillators (SHNOs) are modern auto-oscillation devices. Their simple geometry allows for an optical characterization by Brillouin-Light-Scattering microscopy (μBLS) at room temperature. Here we report on the observation of auto-oscillations in constriction based SHNOs. These are devices where the current density is increased locally due to lateral confinement. Hence, the spin current generated by the spin Hall effect can create well defined hot-spots for auto-oscillations. We present μBLS measurements of auto-oscillations in $Co_{60}Fe_{20}B_{20}$(5 nm)/Pt(7 nm) based samples with two interacting, neighbouring nano-constrictions. The precession amplitude in these samples can be driven far from equilibrium, resulting in clear nonlinear signatures in the spin-wave spectra. The spatial distributions of the observed modes and current dependencies are shown.

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

MA 67.18 Fri 9:30 P2-OG3

Structural insight into spin-orbit effects in metal-oxide/Co/Pt sandwiches — •Martin Kopte[1], T. Kosub[1], U. K. Rössler[2], R. Schäfer[2], A. Kákay[1], F. Radu[3], O. G. Schmidt[2], J. Lindner[1], J. Fassbender[1], and D. Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany — [2]Leibniz-Insitut für Festkörper- und Werkstoffforschung, Dresden, Germany — [3]Helmholz-Zentrum Berlin für Materialien und Energie, Germany

Novel spinorbitronic devices require a subtle control of spin-orbit effects such as Dzyaloshinskii-Moriya interaction (DMI), spin orbit torques (SOT) and magnetoresistance effects. Here we study the impact of interface properties on the strength of these effects in out-of-plane magnetised metal-oxide/Co/Pt sandwiches. The interface-induced DMI in samples prepared with chromium oxide as the metal oxide layer is quantified by using several approaches. A detailed structural investigation of these samples as well as a comparison to the literature data of samples capped with e.g. magnesium or aluminum oxide show that the DMI strength is predominantly determined by the quality of the Pt/Co interface. Within the accuracy of the experimental data at hand we do not find evidence for a recently predicted Rashba-like contribution of the metal-oxide/Co interface to the DMI strength. Quantification of SOT by harmonic analysis of magnetoresistance data provides complementary insight into the crucial structural dependence of spin-orbit effects. Our experimental data and analysis demonstrate the impact on DMI and SOT, and the possibility to tune these effects, by microstructural details in asymmetric layer stacks.

MA 67.19 Fri 9:30 P2-OG3

Time-resolved scanning electron microscopy with polarization analysis — •Fabian Kloodt[1], Robert Frömter[1,2], Philipp Staeck[1], Axel Frauen[1], Susanne Kuhrau[1], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We demonstrate the feasibility of investigating periodically driven magnetization dynamics in a scanning electron microscope with polarization analysis based on spin-polarized low-energy electron diffraction [1]. With the present setup [2], analyzing the time structure of the scattering events, we obtain a temporal resolution of 700 ps, which is demonstrated by means of imaging the field-driven 100 MHz response of a vortex in a soft-magnetic FeCoSiB square. Owing to the efficient intrinsic timing scheme, high-quality movies, giving two components of the magnetization simultaneously, can be recorded on the time scale of hours. The present state of the method, limitations and the development potential will be discussed.

[1] R. Frömter, Appl. Phys. Lett. 108, 142401 (2016).
[2] R. Frömter, Rev. Sci. Instrum. 82, 033704 (2011).

MA 67.20 Fri 9:30 P2-OG3

Calorimetric Experiments on Fe/W(110) using SP-STM — •Hermann Osterhage, Cody Friesen, and Stefan Krause — Universität Hamburg, Department of Physics, Jungiusstrasse 11A, 20355 Hamburg, Germany

The Seebeck effect provides the possibility to use waste heat to drive electric devices. Combined with progressing miniaturisation this offers a chance to increase the efficiency of future circuits.

In our experiment, we use spin-polarized scanning tunneling microscopy (SP-STM) to investigate the magneto-Seebeck tunneling on a very local scale. While the sample is at a temperature of $T = 50$ K, we heat the SP-STM tip by laser irradiation. The resulting thermovoltage between tip and sample is countered by an external bias, yielding zero tunneling current [1]. From the theoretical model of the tunneling process in STM, a proportionality between thermovoltage and tip-sample separation is expected [2]. Experimental results on the Fe/W(110) surface will be shown and compared to this model in terms of the tip-sample separation dependent thermovoltage, and the temperature difference between tip and sample.

[1] D. Hoffmann *et al.*, J. Electron. Spectrosc. Relat. Phenom. **109**, 117 (2000).
[2] J. A. Støvneng *et al.*, Phys. Rev. B **42**, 9214 (1990).

MA 67.21 Fri 9:30 P2-OG3

SEMPA imaging of magnetic spin configurations and manipulation by spin currents — •Daniel Schönke[1], Pascal Krautscheid[1,2], Maike Lauf[1], Benjamin Krüger[1], Robert M. Reeve[1], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany

Control of the magnetic configuration of nanoscale structures is vital for spintronic device applications. The initial magnetic state is mainly set by material parameters and geometry, while manipulation can be realized using spin-transfer and spin-orbit torques. Scanning electron microscopy with polarization analysis (SEMPA) is a powerful imaging technique to investigate these effects with high resolution and surface sensitivity. We demonstrate how specific domain wall types can be tailored in wires by choosing the dimensions [1] and via geometrical confinement at notches. For the vortex state in disks, spin currents are then employed to manipulate the vortex core, with the imaged displacement related to the non-adiabatic torque [2,3]. By rare earth Dy-doping, the damping can be changed and the resulting change of the non-adiabaticity can be probed and compared to the theory [3]. Direct imaging of spin accumulation would be a next step, however remains challenging due to the low signal and other current-induced effects [4]. [1] P. Krautscheid et al., J. Phys. D: Appl. Phys. 49, 425004 (2016). [2] L. Heyne et al., Phys. Rev. Lett. 105, 187203 (2010). [3] A. Bisig et al., Phys. Rev. Lett. (in press 2016), arxiv:1511.06585 [4] P. Riego et al., Appl. Phys. Lett. 109, 172402 (2016).

MA 67.22 Fri 9:30 P2-OG3

High magnetic field gradient tips for single spin resonance

imaging — •Philipp Scheiger, Thomas Oeckinghaus, Rainer Stöhr, Amit Finkler, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart

Due to its high sensitivity to small magnetic fields at room temperature, the nitrogen-vacancy center (NV center) in diamond is a promising tool for resonance imaging of single electron spins in molecules using atomic force microscopy (AFM) techniques under ambient conditions. Using the spin-labels in molecules, the only limitation in imaging single spins in molecules with the NV center, is the spatial resolution. Every electron spin in resonance with the measurement scheme contributes to the signal and thereby reduces the probability of detecting single spins. The aim of this work is to spatially restrict the number of resonant electron spins by using a strong magnetic field gradient. Since strong off-axis magnetic fields disturb the optical readout of the NV center spin state, we try to fabricate magnetic tips with low total magnetic field strength but with a gradient in the range of 10G/nm. Commercially available magnets, like AFM tips, do not generate such fields. This work is split up into three steps, first the micromagnetic simulation of the required geometry, secondly the fabrication of high gradient magnetic on tips and finally the integration of such tips into an AFM setup for measurements with an NV center.

MA 67.23 Fri 9:30 P2-OG3

How to detect magnetically labeled cells using magnetoelectric sensors — •Ron-Marco Friedrich[1], Jan-Martin Wagner[1], Sebastian Zabel[1], Christine Selhuber-Unkel[2], and Franz Faupel[1] — [1]CAU Kiel, Institute for Materials Science, Chair for Multicomponent Materials, Kaiserstr. 2, 24143 Kiel, Germany — [2]CAU Kiel, Institute for Materials Science - Biocompatible Nanomaterials, Kaiserstr. 2, 24143 Kiel, Germany

The detection of magnetically labeled cells has been of great interest in recent years and holds significant possibilities in the field of biomedical sciences for the nondestructive and non-invasive imaging of cells in 3D scaffolds. Here, a new detection method using magnetoelectric (ME) sensors is introduced where, similar to magnetic particle imaging (MPI), the nonlinear magnetization behavior of magnetic particle ensembles is used to detect higher harmonic excitations. These ME sensors, consisting of magnetostrictive and piezoelectric layers on a cantilever, show very high sensitivity anisotropy and sharp mechanical resonance, which leads to selective signal acquisition with regard to spatial orientation and excitation frequency. Using such inherent features of the sensor and the nonlinear magnetization behavior of nanoparticles, the objective is to detect and locate cells by scanning over the sample with the detector while applying a homogeneous alternating magnetic field. To achieve this objective, we formulate the restrictions and necessities of the detection system and analyze them with regard to measureable fields, particle densities, external magnetic fields, excitation frequencies and sensor orientations.

MA 67.24 Fri 9:30 P2-OG3

Nanoscale temperature sensing for a new generation of hard disk recording heads — •Sven Bodenstedt[1], Ingmar Jakobi[1], Fadi El Hallak[2], Philipp Neumann[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Seagate Technology

State of the art hard disk recording heads use magnetic fields to encode data as magnetization on small sectors on a recording medium. A new generation of recording heads, called Heat Assisted Magnetic Recording (HAMR) [1], employs an additional nanoscopic heat spot to reduce the coercivity of a single recording bit on the recording medium. Although HAMR heads are not yet available in commercial drives this technology may increase storage capacities by orders of magnitude.

The development of the device hinges on suitable sensors for the nanoscale characterization of the produced heat. Nitrogen-vacancy (NV) defect centers in diamond are the ideal candidate for this task. In addition to being efficient magnetometers that can be used to survey the magnetic field of recording heads [2] they are also sensitive to temperature changes [3, 4]. Here we present our work to bring a NV nanoscale thermometer to the hard disk industry.

[1] M. Krayder et al., Proceedings of the IEEE, 2008
[2] I. Jakobi et al., Nature Nanotechnology, 2016
[3] P. Neumann et al., Nano Letters, 2013
[4] A. Laraoui et al., Nature Communications, 2015

MA 67.25 Fri 9:30 P2-OG3

Scanning Tunneling Microscopy in the Field Emission regime revisited — •Gabriele Bertolini, Lorenzo G. De Pietro, Oguzhan Gürlü, Urs Ramsperger, and Danilo Pescia — ETH Zurich, Zurich, Switzerland

In a Scanning Tunnelig Microscope retracting the tip from the sample by 5 to 100 nm and applying a suitable junction bias (-10 to -100 V tip bias) between them bring the tip-sample junction out of the tunnelling regime and the tip becomes a source of electrons due to field emission. In this regime the electrons arriving from the tip to the sample cause the generation of secondary electrons on the sample surface, which can escape from the tip-sample junction. Such electrons may be collected by several means and analysed. This technique is called as Field Emission Scanning Probe Microscopy. The strong dependence of the physical properties of the secondary electrons on the nature of the sample surface makes complementary information accessible. Besides the emitted and absorbed current maps and the z-piezo displacement images of the surface, chemical and magnetic contrast with nanometer scale resolution can be achieved on the same region that was scanned previously in the STM mode. We are currently aiming at detecting the spin polarization of the secondary electrons, for the purpose of magnetic imaging. In this presentation structural and electronic properties obtained on several pure-metallic and compound surfaces with previously not reported lateral resolution will be discussed.

MA 67.26 Fri 9:30 P2-OG3

Spectral properties of the longitudinal spin Seebeck effect — •Timo Noack, Thomas Langner, Frank Heussner, Viktor Lauer, Oleksandr Serha, Burkard Hillebrands, and Vitaliy Vasyuchka — Fachbereich Physik der TU Kaiserslautern und Landesforschungszentrum OPTIMAS, 67663 Kaiserslautern, Germany

The transitional dynamics of the longitudinal spin Seebeck effect (LSSE) was investigated in YIG/Pt bilayers. Two experimental approaches were used to measure LSSE in a wide range of YIG thicknesses. Firstly, a pulsed microwave signal was applied to the structure and the subsequent thermal gradient gives rise to a LSSE-voltage pulse, which was measured by an oscilloscope. Over the thickness range from 270 nm to 53 μm we observed an increase of the rise-time by a factor of 42. Secondly, the heating microwave signal was modulated by a low-frequency signal and the LSSE-voltage was measured for different modulation frequencies. The cut-off frequency was extracted from the LSSE transfer function. It shows an inverse proportional dependence to the magnetic layer thickness. Both experiments can be understood by considering the transfer properties of the magnons in their diffusive process. Financial support by the Deutsche Forschungsgemeinschaft within SPP 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 67.27 Fri 9:30 P2-OG3

Towards an understanding of the basic mechanism of hysteresis at a first-order magneto-structural transition — •F. Scheibel[1], Ö. Çakir[2], T. Gottschall[3], M. Ghorbani Zavareh[4,5], C. Salazar Mejia[4], Y. Skourski[4], F. Cugini[6], A. Tekgül[7], O. Gutfleisch[3], J. Wosnitza[4], M. Solzi[6], M. Farle[1], and M. Acet[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Physics Department, Yildiz Technical University, 34349 Istanbul, Turkey — [3]Materialwissenschaft FG Funktionale Materialien , Technische Universität Darmstadt, 64289 Darmstadt, Germany — [4]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [5]Chemical Physics of Solids, Max-Planck-Institute, 01187 Dresden, Germany — [6]Physics Department and CNISM, University of Parma, 43121 Parma, Italy — [7]Physics Department, Akdeniz University, 07058 Antalya, Turkey

The reversibility of the adiabatic temperature change ΔT in materials with a first-order magneto-structural transition (FOMST) is limited by the thermal hysteresis of the transition, making it a critical factor for refrigeration applications. Adiabatic magnetization and ΔT studies with different field-change rates up to 700 T/s are performed to understand the dynamics of the FOMST for antiperovskites, Heuslers, and transition metal pnictides. In particular, the effect of long range ferromagnetic ordering on the hysteresis is investigated. Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

MA 67.28 Fri 9:30 P2-OG3

First Principles Calculations towards the Magnetic Phase Diagram of Quaternary Heusler Alloys — •Marianne Schröter, Anna Grünebohm, and Peter Entel — Universität Duisburg-Essen, Germany

Recently magnetic Heusler alloys have become of interest because of their giant inverse magnetocaloric effect and its desirous relevance for magnetic refrigeration[1]. Adding elements to the ternary Heusler alloys can tune the effect[2].

We investigate the influence of Cr and Co as quarternary elements on the magnetic phase diagram of NiMnGa. On the basis of DFT supercell calculations we look at the energy landscapes of theses alloys for different magnetic phases. KKR-CPA calculations together with subsequential Monte Carlo simulations highlight the degree of magnetic frustration in these systems. In the case of Cr for Ni substitution we see that energetically favoured are those states where the magnetic moments of Mn moments are ferromagnetically aligned. On the other hand the total magnetization is reduced by the antiferromagnetic alignment of Cr.

[1] K. A. Gschneidner et al., Rep. Prog. Phys. 68, 1479 (2005)
[2] V. V. Sokolovskiy et al., Phys. Rev. B 91, 220409(R) (2015)

MA 67.29 Fri 9:30 P2-OG3

Direct measurements of ΔT in magnetocaloric and electrocaloric samples utilizing modulated fields at variable frequencies — •Jago Döntgen[1], Jörg Rudolph[1], Steffen Salomon[2], Alfred Ludwig[2], Tino Gottschall[3], Oliver Gutfleisch[3], Anja Waske[4], Sylvia Gebhardt[5], and Daniel Hägele[1] — [1]AG Spektroskopie d. kondensierten Materie, Ruhr-Universität Bochum — [2]Werkstoffe der Mikrotechnik, Ruhr-Universität Bochum — [3]Funktionale Materialien, Technische Universität Darmstadt — [4]Institut für komplexe Materialien, IFW Dresden — [5]Multifunktionale Werkstoffe und Bauteile, Fraunhofer IKTS Dresden

We present magneto- and electrocaloric data taken by our newly developed non-contact technique for direct measurements of the adiabatic temperature change in modulated fields. High field frequencies allow for magnetocaloric measurements on low volume samples, as demonstrated on a gadolinium film as thin as 1.4 μm. The dynamic behaviour of hydrogenated La-Fe-Si and gadolinium is investigated by applying modulated magnetic fields at varying frequencies up to 1.2 kHz. The experimental setup is further used to measure the electrocaloric effect in the relaxor dielectric PMN-PT, which exhibits a pronounced ageing behaviour both in its dielectric and electrocaloric properties.

MA 67.30 Fri 9:30 P2-OG3

Structural characterization of multicaloric, epitaxial Ni-Mn-Ga-Co thin films on piezoelectric substrates — •Stefan Schwabe[1,2], Benjamin Schleicher[1], Robert Niemann[1], Anja Waske[1], Ruben Hühne[1], Kornelius Nielsch[1,2], and Sebastian Fähler[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany. — [2]TU Dresden, Institute of Materials Science, D-01069 Dresden, Germany.

Heusler alloys of the type Ni-Mn-Co-X (with X = Ga, In, Sb, Sn) are a promising material class for solid state cooling applications. They undergo a phase transition between the austenite at high and the martensite at lower temperatures accompanied by a reduction of crystal symmetry and the occurrence of an inverse magnetocaloric effect. This transformation can be influenced by the temperature, an applied magnetic field, but also mechanical stress. An epitaxial growth of thin films offers a well-defined orientation relation making it possible to model the structure of the twinned, low symmetry phase. Therefore, thin films were prepared on piezoelectric substrates and mechanically stressed by the application of an electric field. We present an investigation of Ni-Mn-Ga-Co thin films on piezoelectric PMN-PT substrates, which were grown epitaxially via sputter deposition. The structure of the martensite was probed with different X-ray diffraction methods, including 2D synchrotron XRD-measurements. The diffraction patterns are compared to calculated ones using the phenomenological martensite theory to examine the martensitic structure and influence of the stress. This work is supported by DFG through SPP 1599, www.FerroicCooling.de.

MA 68: Poster 5

Time: Friday 9:30–13:00 Location: P2-OG4

MA 68.1 Fri 9:30 P2-OG4

Investigation of thermalization in giant-spin models by different Lindblad schemes — •Christian Beckmann and Jürgen Schnack — Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld

The theoretical understanding of time-dependence in magnetic quantum systems is of great importance in particular for cases where a unitary time evolution is accompanied by relaxation processes. A key example is given by the dynamics of single-molecule magnets where quantum tunneling of the magnetization competes with thermal relaxation over the anisotropy barrier. In this contribution we investigate how good a Lindblad approach describes the relaxation in giant spin models and how the result depends on the employed operator that transmits the action of the thermal bath.

MA 68.2 Fri 9:30 P2-OG4

High-frequency EPR studies on lanthanide monomers in different ligand structures — •Julian Butscher[1], Changhyun Koo[1], Johannes Werner[1], Asha Roberts[2], Peter Comba[2], and Rüdiger Klingeler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Anorganisch-Chemisches Institut, Universität Heidelberg, Heidelberg, Germany

4f-lanthanide single molecular magnets (SMMs) find increasing interest in the SMM research field due to their high magnetic anisotropy caused by strong spin-orbit coupling in Ln ions. We report the magnetic properties of Ln monomers (Ln = Dy(III) and Tb(III)) in different ligand structures ([Dy(III)(2Li-1,2-HOPo)$_2$]pyH, [Tb(III)(2Li-1,2-HOPO)$_2$]PyH, and [Tb(III)(5Li-1,2-HOPO)$_2$]PyH) which are studied by means of high-field magnetometry and high-frequency electron paramagnetic resonance (HF-EPR). The HF-EPR spectra of all complexes, at T = 2 K, exhibit only a single resonance feature which frequency linearly increases with the external magnetic field. The associated g-factors much larger than 2 are read-off the frequency vs. magnetic field diagrams. Finite zero-field splitting (ZFS) is observed in the [Tb(III)(2Li-1,2-HOPO)$_2$]PyH-complex which indicates lifting of the degeneracy in a non-Kramers doublet. The ground states of the complexes are estimated by using high-field magnetization and HF-EPR measurements, as well as by energy level calculations.

MA 68.3 Fri 9:30 P2-OG4

Tuneable electronic structure and molecular magnetism in metal organic frameworks — •Sebastian Schwalbe[1], Kai Trepte[2], Gotthard Seifert[2], and Jens Kortus[1] — [1]TU Bergakademie Freiberg, Institute for Theoretical Physics, Germany — [2]Technische Universität Dresden, Theoretical Chemistry, Germany

We present an ab-initio density functional theory study and show how it is possible to tune the electronic structure and with that the local magnetism represented by single molecule magnets (SMMs) within three-dimensional metal organic frameworks (MOFs). The electronic and magnetic properties of the flexible MOF DUT-8(Ni) [1,2] were described by Trepte et al. [3]. Based on this work we performed a screening of the metal centers in a special model system [4], which is a good approximation for the electronic and magnetic properties of DUT-8(Ni). A major result of these calculations is that the electronic structure is mainly determined and influenced by the metal centers (3d metals). By changing the metal centers inside the SBU we are able to adjust magnetic properties and obtain stable ferromagnetic, antiferromagnetic or eventually even metallic secondary building units.

[1] N. Klein et al., PCCP, vol. 12, pp. 11778-11784, 2010
[2] V. Bon et al., PCCP, vol. 17, pp. 17471-17479, 2015
[3] K. Trepte et al., PCCP, vol. 17, pp. 17122-17129, 2015
[4] S. Schwalbe et al., PCCP, vol. 18, pp. 8075-8080, 2016

MA 68.4 Fri 9:30 P2-OG4

Field-induced exciton condensation in $LaCoO_3$ — •Andrii Sotnikov and Jan Kuneš — Institute of Solid State Physics, TU Wien, Austria

Motivated by recent observation of magnetic field induced transition in $LaCoO_3$ [1] we study the effect of external field in systems close to instabilities towards spin-state ordering and exciton condensation. We show that, while in both cases the transition can be induced by an external field, temperature dependencies of the critical field have opposite slopes [2]. Based on this result we argue that the experimental observations select the exciton condensation scenario. We show that such condensation is possible due to high mobility of the intermediate spin excitations. The estimated width of the corresponding dispersion is large enough to overrule the order of atomic multiplets and to make the intermediate spin excitation propagating with a specific wave vector the lowest excitation of the system.

[1] A. Ikeda *et al.*, Phys. Rev. B **93**, 220401 (2016).
[2] A. Sotnikov and J. Kuneš, Sci. Rep **6**, 30510 (2016).

MA 68.5 Fri 9:30 P2-OG4

Functional approach to electrodynamics of media — •Ronald Starke[1] and Giulio Schober[2] — [1]Institut für Theoretische Physik, TU Bergakademie Freiberg, Leipziger Str. 23, 09596 Freiberg — [2]Institute for Theoretical Physics, Heidelberg University, Philosophenweg 19, 69120 Heidelberg

By a systematic investigation of the mutual functional dependencies between induced, external and total electromagnetic field quantities we derive universal (material-independent) relations between electromagnetic response functions such as the dielectric tensor, the magnetic susceptibility and the microscopic conductivity tensor. Our formulae can be reduced to well-known identities in special cases, but more generally include the effects of inhomogeneity, anisotropy, magnetoelectric cross-coupling and relativistic retardation. If combined with the Kubo formalism, they would therefore lend themselves to the ab initio calculation of all linear electromagnetic response functions, thus paving the way for a first-principles description of magneto-electric materials for spintronics applications.

MA 68.6 Fri 9:30 P2-OG4

Resonant inelastic X-ray scattering study of excitonic condensation in perovskite cobalt oxides — •Atsushi Hariki and Jan Kuneš — Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria

Spin-state transition in perovskite cobalt oxides, such as $LaCoO_3$, is an open problem in the research of the strongly correlated electron systems. Recently, the instability towards the excitonic condensation (EC) close to the spin-state transition was theoretically studied [1,2]. However, experimental probe to detect the EC in perovskite cobalt oxides has not been realized so far.

In this study, we propose that Co $L_{2,3}$-edge resonant inelastic X-ray scattering (RIXS) is a promising experimental method to investigate the EC in perovskite cobalt oxides. We analyze the angular dependence of $L_{2,3}$ RIXS by means of an atomic model considering the effect of the EC and show that RIXS gives a distinctive spectral feature of the EC state in comparison with the contributions of the pure (atomic) spin-states (such as high-, low- and intermediate-spin states) discussed in the context of the spin-state transition so far.

[1] J. Kuneš et al., Phys. Rev. B 89, 115134 (2014).
[2] J. Kuneš et al., Phys. Rev. B 90, 235112 (2014).

MA 68.7 Fri 9:30 P2-OG4

Excitonic condensation in $LaCoO_3$ perovskite — •Juan Fernandez Afonso and Jan Kunes — Technische Universität Wien, Freihaus building, Wiedner Hauptstrasse 8 -10, 1040 Wien, AUSTRIA

We study the possibility of excitonic condensation in transition metals perovskites with d^6 electronic configuration such as $LaCoO_3$. These excitonic states arise from an intra-atomic $e_g - t_{2g}$ electron-hole coupling. It is possible to characterise them by a 3×3 complex order parameter. We present several LDA+U self-consistent solutions which correspond to distinct ordered states. We study both stability and symmetry properties of these solutions, investigate the evolution of the order parameter with the interaction strength and the effect that the spin-orbit coupling has on these states. Our results suggest that $LaCoO_3$ is close to the excitonic instability and suggest ways how the instability can be reached in the reality.

MA 68.8 Fri 9:30 P2-OG4

Domain engineering in the $4f$ uniaxial ferromagnet $CeRu_2Ga_2B$ — •Dirk Wulferding[1,2], Hoon Kim[1,3], Ilkyu Yang[1,3], Oscar Ayala-Valenzuela[1], Roman Movshovich[4], Ryan Baumbach[5], Eric Bauer[4], Joe Thompson[4], Leonardo Civale[4], and Jeehoon Kim[1,3] — [1]CALDES, Institute for Basic Science, Pohang, Korea — [2]IPKM und LENA, TU-BS, Braunschweig, Germany — [3]Dept. of Phys., POSTECH, Korea — [4]MPA-CMMS, Los Alamos Natl. Lab., Los Alamos, USA — [5]NHML, Florida State Univ., Tallahassee, USA

The interplay of spin and electronic degrees of freedom in strongly correlated electron systems is a fruitful route towards many exotic and unexpected phenomena. In particular, rich magnetic phase diagrams can be found in systems with additional magnetic anisotropies. While the bulk magnetic properties are often well explored, the evolution of the microscopic magnetic domain structure within the phase diagram remains elusive. Using low temperature magnetic force microscopy with vector magnet capabilities [1], we explore the evolution and manipulation of magnetic domains in the centrosymmetric ferromagnet $CeRu_2Ga_2B$ [2]. This compound exhibits transitions among dendritic, stripe, and bubble domain phases. We highlight the domain evolution with a vector magnetic field in this Ising-like spin system and demonstrate the manipulation of individual bubble domains through the magnetic tip of our scanning probe microscope.

[1] Yang, et al., Rev. Sci. Instrum. 87, 023704 (2016). [2] Baumbach, et al., J. Phys.: Condens. Matter 24, 185702 (2012).

MA 68.9 Fri 9:30 P2-OG4

Resonant Elastic X-ray Scattering (REXS) from the helical phase in Cu_2OSeO_3 at VEKMAG — •Simon Pöllath[1], Chen Luo[1], Martin Schön[1], Florin Radu[2], Hanjo Ryll[2], and Christian Back[1] — [1]Universität Regensburg Institut für Experimentelle und Angewandte Physik, Regensburg, Deutschland — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Deutschland

We report successful Resonant Elastic X-ray Scattering (REXS) experiments at the BESSY II PM2 VEKMAG beamline. We investigate a single crystalline Cu_2OSeO_3 sample grown by the chemical vapor transport method. The multiferroic insulator Cu_2OSeO_3 hosts a variety of magnetically modulated states at weak externally applied fields and below its critical Temperature. In the helical phase of the chiral magnet, the structural (001) Bragg peak shows a multiple splitting at the Cu L3 edge energy, caused by the modulated magnetic texture. Reciprocal space maps of the helical phase are obtained using a pin-hole diode. Additionally, the thermodynamic phase diagram is accessible from magnetization loops of the Bragg peak intensity. The vector magnet enables precise control of the modulation directions for future studies of conical and skyrmionic phases.

MA 68.10 Fri 9:30 P2-OG4

First-principles calculations of chiral magnetic structures in multilayers: {Rh|Co|Pt} and {Pd|Co|Pt} — •Hongying Jia, Bernd Zimmermann, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich

The Dzyaloshinskii-Moriya interaction (DMI), which is an antisymmetric exchange interaction, plays an important role in determining the physical properties of surfaces and interfaces of low-dimensional metallic magnets, in particular for the formation of magnetic skyrmions.

Here, we determine the magnetic interaction parameters of the magnetic multilayers of {Rh|Co|Pt} and {Pd|Co|Pt} using first-principles calculations based on the full-potential linearized augmented planewave (FLAPW) method, which is implemented in the `FLEUR` code [1].

We find that the $4d$ (i.e. Rh and Pd) elements induce a DMI that partly cancels the large DMI produced by the heavy-metal Pt layer. Upon variation of the thickness of the Pt layer between one and five atomic layers, we investigate the interlayer exchange coupling between the magnetic Co layers. For the {Pd|Co|Pt} system, a RKKY-type oscillatory behavior between ferromagnetic and antiferromagnetic interactions is observed. The {Rh|Co|Pt} system has a qualitatively different behavior, where frustrations in between the Co layers lead to a non-collinear order along the c axis.

We acknowledge financial support from the MAGicSky Horizon 2020 European Research FET Open project (#665095).

[1] For the program description see http://www.flapw.de.

MA 68.11 Fri 9:30 P2-OG4

Electric coupling of magnetic monopoles in the quantum spin-ice $Pr_2Hf_2O_7$ — •Jacob Hornung[1,2], Lars Opherden[1,2], Thomas Herrmannsdörfer[1], Alexandros Samartzis[3], Bella Lake[3,4], and Jochen Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, Germany — [3]Abteilung Quantenphänomene in neuen Materialien, HZB, Berlin, Germany — [4]Institut für Festkörperphysik, TU Berlin, Germany

We report on the magnetoelectric coupling of magnetic monopole excitations in the quantum spin-ice material $Pr_2Hf_2O_7$. We have investigated $Pr_2Hf_2O_7$ single crystals by means of dynamic permittivity and susceptibility measurements down to 100 mK. The ac susceptibility, its frequency, field, and temperature dependence, and its saturation at a finite value in the low-temperature limit indicate the formation of a quantum spin-ice state. The permittivity shows a clear correlation to the monopole density and an anomaly in magnetic fields along the local [111] direction. This hints at a charge redistribution on the magnetic monopole sites, leading to the formation of electric dipole moments.

MA 68.12 Fri 9:30 P2-OG4

NMR of the frustrated spin-ladder system Copper Sulfolane — •D. Dmytriieva[1,2], Z. T. Zhang[1,3], M. Naumann[1], J. Wosnitza[1,2], E. Wulf[4], A. Zheludev[4], and H. Kühne[1] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, Germany — [3]Institute of Ion Beam Physics and Materials Research, HZDR, Dresden, Germany — [4]Neutron Scattering and Magnetism, Laboratory for Solid State Physics, ETH Zuerich, Switzerland

We present results from NMR experiments on the geometrically frustrated quantum magnet Copper Sulfolane. The ground state is a disordered spin liquid that evolves into a chiral helimagnetic phase at fields above about 4 T. NMR of ^{35}Cl nuclei on two nonequivalent sites was performed to map the local susceptibility and charge-gradient tensors close to the Cu^{2+} $S = 1/2$ moments. The field-driven transition into the helimagnetic state, probed via ^{13}C NMR, yields a drastic increase of slow spin fluctuations, manifested as a sharp maximum of the nuclear spin-lattice relaxation rate. Further, we investigated the effect of a dilute and random modification of the local frustration ratio, introduced by Br substitution on the nonmagnetic halogen site. Bulk thermodynamic measurements indicate that surprisingly small Br concentrations have a strong impact on the magnetic correlations of the helimagnetic state. In line with these findings, we observed a strong suppression of the dynamic properties with Br substitution.

MA 68.13 Fri 9:30 P2-OG4

The magnetic phase diagram of the frustrated spin-chain linarite as seen by neutron diffraction — •Leonie Heinze[1], Britta Willenberg[1,2], Jens-Uwe Hoffmann[2], Anja U. B. Wolter-Giraud[3], Kirrily C. Rule[4], Bachir Ouladdiaf[5], and Stefan Süllow[1] — [1]IPKM, TU Braunschweig, Germany — [2]HZB, Berlin, Germany — [3]IFW Dresden, Dresden, Germany — [4]ANSTO, Kirrawee, Australia — [5]ILL, Grenoble, France

Linarite, $PbCuSO_4(OH)_2$, has been established as a model compound of the frustrated one-dimensional spin-1/2 chain with ferromagnetic nearest-neighbor and antiferromagnetic next-nearest-neighbor interactions [1,2]. Recently, a complex magnetic phase diagram has been reported for linarite in fields $B\|b$ axis for temperatures below 2.8 K consisting of five regions [3]. In particular, the so-called phase V has been established as an incommensurate spin density wave (SDW) phase as predicted by theory.

Here, we present an elastic neutron diffraction study on linarite of the magnetic phase diagram $B\|b$, with special emphasis on phase V. This way, the temperature and field dependence of the magnetic moment were established for temperatures down to 50 mK and fields up to 9.5 T. Further, the field and temperature dependence of the incommensurability vector **q** of the SDW in phase V was established. Finally, the nature of the phase transition IV-V being of first order was derived.

[1] A.U.B. Wolter et al., Phys. Rev. B **85**, 014407 (2012).
[2] B. Willenberg et al., Phys. Rev. Lett. **108**, 117202 (2012).
[3] B. Willenberg et al., Phys. Rev. Lett. **116**, 047202 (2016).

MA 68.14 Fri 9:30 P2-OG4

Breakdown of 3D topological order in a magnetic field — •David Reiss and Kai Phillip Schmidt — Lehrstuhl für Theoretische Physik I, Staudtstraße 7, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

Intrinsic topological order in three dimensions represents interesting quantum phases featuring exotic elementary excitations which are spatially extended and have anyonic statistics different from bosons and fermions. Such phases can exist at finite temperatures and might serve as future error-correcting quantum memories. One paradigmatic example of 3D topological order is Kitaev's toric code, which has a nonzero topological entanglement entropy at finite temperatures in contrast to the conventional 2D case. This phase can arise as effective low-energy Hamiltonian of 3D generalizations of the frustrated Kitaev honeycomb model which might describe frustrated quantum magnets like certain iridate compounds.

Here we study the robustness of the 3D toric code against quantum fluctuations by investigating the zero-temperature phase diagram of the 3D toric code in an arbitrary uniform magnetic field.

MA 68.15 Fri 9:30 P2-OG4

Monopole heat transport and residual entropy in dilute spin ice $(Dy_{1-x}Y_x)_2Ti_2O_7$ — •Daniel Brüning, Simon Scharffe, Jean-Francois Welter, Gerhard Kolland, and Thomas Lorenz — II. Physikalisches Institut, Universität zu Köln, Deutschland

The spin ice $Dy_2Ti_2O_7$ is a geometrically frustrated spin system of corner-sharing tetrahedra with an Ising anisotropy. In the ground state configuration two spins point into and two out of each tetrahedron. The lowest excitation in spin ice systems is a single spin flip which creates a pair of 1in-3out and 3in-1out configurations on neighboring tetrahedra. Such a pair can fractionalize into two individual excitations, namely magnetic monopoles, that can propagate almost independently within the pyrochlore lattice. The entropy of $Dy_2Ti_2O_7$ reveals a plateau-like feature close to Pauling's residual entropy around 0.5 K derived originally for water ice. Ultraslow thermal equilibration prevents a distinct expansion towards lower temperature. We analyze the influence of non-magnetic yttrium dilution on the low-temperature entropy of $(Dy_{1-x}Y_x)_2Ti_2O_7$. The ultraslow thermal equilibration rapidly vanishes with increasing x, the low-temperature entropy systematically decreases, and its temperature dependence strongly increases. From our data, a non-degenerate ground state can be derived that is compared to different theoretical approaches. Additionally, we present the heat transport data of the dilution series, which give insight in the monopole transport contribution.

Supported by the DFG via CRC 1238 and project LO 818/2-1.

MA 68.16 Fri 9:30 P2-OG4

Quantum phase diagram of a bilayer Kitaev model with interlayer Heisenberg interaction — •Julian Gritsch[1], Matthias Vojta[2], and Kai Phillip Schmidt[1] — [1]FAU Erlangen-Nürnberg, Erlangen, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

The Kitaev honeycomb model is an extensively studied two-dimensional quantum spin model exhibiting exotic spin-liquid phases. In this project, we study two layers of the Kitaev honeycomb model coupled by a Heisenberg interaction and we focus on the regime where the isolated Kitaev models would be in the topologically ordered Abelian phase. Consequently, as a function of the interlayer coupling, there must be at least one quantum phase transition separating the topologically ordered phase from the valence bond solid present at large interlayer Heisenberg coupling where the ground state is adiabatically connected to the limit of isolated singlets. In this work we study this quantum phase transition by investigating the elementary excitations of both quantum phases.

MA 68.17 Fri 9:30 P2-OG4

Dielectric spectroscopy of doped spin ice — •Lena Klaas, C. P. Grams, J. Engelmayer, T. Lorenz, and J. Hemberger — II. Physikalisches Institut, Universität zu Köln, Cologne, Germany

Spin-ice systems have raised strong interest due to the emergence of magnetic monopoles. In $Dy_2Ti_2O_7$ the condensation of these excitations was demonstrated to undergo a first-order phase transition with a critical endpoint at T=0.36 K and $\mu_0 H$=1 T in crystallographic [111]-direction. Furthermore, magnetic monopoles also carry electric dipoles[1], making their dynamics accessible by dielectric spectroscopy. Measurements on $Dy_2Ti_2O_7$ have demonstrated unusual fluctuation dynamics above the critical temperature, a *critical speeding-up*[2]. To investigate the influence of defects on this relaxation dynamics we studied the system $(Dy_{1-x}Y_x)_2(Ti_{1-y}Zr_y)_2O_7$ with different doping levels of non-magnetic Y^{3+}- or Zr^{4+}-ions. Here, we show dielectric measurements up to frequencies of 1 MHz and down to temperatures of 0.2 K and demonstrate that critical speeding-up is observed for Y doping with x up to 10% above which the spin-ice behaviour is suppressed[3].

Supported by the Deutsche Forschungsgemeinschaft through Projects HE-3219/2-1, LO-818/2-1, and CRC 1238.

[1] D. I. Khomskii, Nat. Commun. **3**, 1-13. (2012)
[2] C. P. Grams, M. Valldor, M. Garst, and J. Hemberger, Nat. Commun. **5**, 4853. (2014)
[3] S. Scharffe, O. Breunig, V. Cho, P. Laschitzky, M. Valldor, J. F.Welter, and T. Lorenz, Phys. Rev. B **92**, 180405 (2015)

MA 68.18 Fri 9:30 P2-OG4

Nonlinear dynamics of topological spin systems — •Alexander F. Schäffer and Jamal Berakdar — Martin-Luther-Universität Halle-Wittenberg, Germany

Topological spin systems are one of the most interesting topics both from a fundamental and application point of view.

In this contribution we present research on the nonlinear dynamics in such systems with particular emphasis on the creation and annihilation of these topologically protected objects. We investigate possible ways to drive and control skyrmionic materials via external fields such as those imparted electron beams or by material composition such as composite engineered multiferroic systems.

MA 68.19 Fri 9:30 P2-OG4

Investigation of pyrochlore spin-ice compounds with reduced lattice parameters — •T. Stöter[1,2], M. Antlauf[3], L. Opherden[2], M. Doerr[1], E. Kroke[3], T. Herrmannsdörfer[2], and J. Wosnitza[1,2] — [1]Institut für Festkörperphysik/TU Dresden — [2]Hochfeld-Magnetlabor Dresden/Helmholtz-Zentrum Dresden-Rossendorf — [3]Institut für Anorganische Chemie/TU Bergakademie Freiberg

The pyrochlores $R_2X_2O_7$ (R = rare earth, X = Ti, Ge, Sn, Hf, ...) have attracted interest for their geometrical frustration from which unusual magnetic states such as spin-ice emerge. Possibly, the effective interaction comes from the competition of dipolar and exchange interaction. The strength of these competing interactions strongly depends on the distance between magnetic moments, i.e., the lattice parameters. Materials with small lattice parameters are most promising to have new interesting properties. The germanate pyrochlore $Dy_2Ge_2O_7$ possesses one of the smallest known lattice constants (a = 9.929 Å), requiring high pressures over 5 GPa for its synthesis. Additionally, we applied high-pressure synthesis of more than 10 GPa to produce pyrochlores with even smaller lattice parameters by partially substituting silicon for germanium using the multianvil technique. First results on the evolution of magnetization and susceptibility down to cryogenic temperatures will be reported.

The work is supported by DFG (SFB 1143).

MA 68.20 Fri 9:30 P2-OG4

XMCD and RXR study of the magnetic and electronic properties of Vanadium-doped TIs — •Abdul-Vakhab Tcakaev[1], Volodymyr Zabolotnyy[1], Michael Dettbarn[1], Benjamin Katter[1], Enrico Schierle[2], and Vladimir Hinkov[1] — [1]University Würzburg, Am Hubland, 97074 Würzburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert Einstein-Str. 15, 12489 Berlin.

Bismuth and antimony tellurides, Bi_2Te_3 and Sb_2Te_3, and the alloys based on these materials play a significant role in thermoelectric technology. Recently these materials became most famous as topological insulators (TIs) with potential applications in spintronics.

Here we report on electronic and magnetic properties of vanadium-doped thin films (10 nm) of $(Bi_{1-x}Sb_x)_2Te_3$ that were grown by molecular beam epitaxy on Si(111) substrates [1]. First-principle calculations predict that vanadium orders ferromagneticaly in Bi_2Te_3 at sufficiently high concentrations. Due to its non-destructive nature and element-specificity, Resonant X-Ray Reflectivity (RXR) in combination with x-ray magnetic circular dichroism (XMCD) is an optimal experimental tool to study magnetic and electronic properties of vanadium-doped TIs. XMCD sum rules allow to extract spin and orbital moments separately. The sum rules can be readily applied for the late 3d transition metals, but for the V complex structure of absorption edge complicates deconvolution of the individual $L_{2,3}$ contributions. To resolve this difficulty we supplement our experimental data with crystal field calculations. [1] S. Grauer *et al.*, Phys. Rev. B 92, 201304(R), 2015.

MA 68.21 Fri 9:30 P2-OG4

Absence of strong skew scattering in crystals with multi-sheeted Fermi surfaces — •Albert Hönemann[1], Christian Herschbach[1], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]University of Bristol, Bristol, United Kingdom

Transport phenomena caused by spin-orbit coupling like spin Hall effect (SHE) [1] and anomalous Hall effect (AHE) [2] are highly interesting topics of current research. In magnetic materials both effects can be observed simultaneously to explore underlying microscopic processes.

Using an *ab initio* relativistic Kohn-Korringa-Rostoker method [3] to solve the linearized Boltzmann equation [4,5], we investigated SHE and AHE for Fe, Co and Ni crystals alloyed with transition metals or Bi. In the considered dilute alloys the dominant extrinsic contribution to both effects is caused by skew scattering [6]. Nevertheless, the strength of skew scattering in these systems is greatly reduced compared to others [7-9]. Our study attributes this to the number of sheets in the host system's Fermi surface. We also discuss different relations between SHE and AHE present in the considered alloys.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015); [2] Nagaosa *et al.*, Rev. Mod. Phys. **82**, 1539 (2010); [3] Gradhand *et al.*, PRB **80**, 224413 (2009); [4] Gradhand *et al.*, PRL **104**, 186403 (2010); [5] Zimmermann *et al.*, PRB **90**, 220403(R) (2014); [6] Lowitzer *et al.*, PRL **106**, 056601 (2011); [7] Gradhand *et al.*, PRB **81**, 245109 (2010); [8] Niimi *et al.*, PRL **109**, 156602 (2012); [9] Fedorov *et al.*, PRB **88**, 085116 (2013).

MA 68.22 Fri 9:30 P2-OG4

Multi-orbital quantum antiferromagnetism in iron pnictides — effective spin couplings and quantum corrections to sublattice magnetization — •Sayandip Ghosh[1,2], Nimisha Raghuvanshi[1], Shubhajyoti Mohapatra[1], Ashish Kumar[1], and Avinash Singh[1] — [1]Department of Physics, Indian Institute of Technology, Kanpur, India 208016 — [2]Institute for Theoretical Physics, TU Dresden, D-01062 Dresden, Germany

Effective spin couplings and spin fluctuation induced quantum corrections to sublattice magnetization are obtained in the stripe AFM state of a realistic three-orbital interacting electron model involving xz, yz, and xy Fe 3d orbitals, providing insight into the multi-orbital quantum antiferromagnetism in iron pnictides. The xy orbital is found to be mainly responsible for the generation of strong ferromagnetic spin coupling in the b direction, which is critically important to fully account for the spin wave dispersion as measured in inelastic neutron scattering experiments. The ferromagnetic spin coupling is strongly suppressed as the xy band approaches half filling, and is ascribed to particle-hole exchange in the partially filled xy band. The strongest AF spin coupling in the a direction is found to be in the orbital off-diagonal sector involving the xz and xy orbitals. First order quantum corrections to sublattice magnetization are evaluated for the three orbitals, and yield a significant 37% average reduction from the Hartree-Fock value.

MA 68.23 Fri 9:30 P2-OG4

Discrete magnetic layer-by-layer switching in antiferromagnetically coupled Fe/MgO(001) superlattices — •Tobias Warnatz[1], Fridrik Magnus[2], Gunnar K. Palsson[1], Vassilios Kapaklis[1], Victor Ukleev[1,3], Reda Moubah[4], Anton Devishvili[1], Justinas Palisaitis[5], Per O. Å. Persson[5], and Björgvin Hjörvarsson[1] — [1]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [2]Science Institute, University of Iceland, Reykjavik, Iceland — [3]RIKEN Center for Emergent Matter Science, Wako-shi, Japan — [4]Faculté des Sciences, Université Hassan II-Casablanca, Casablanca, Morocco — [5]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden

Multilayer structures with an insulating spacer layer are widely studied due to their huge tunnel-magnetoresistance. However, it is less well known (and studied) that such structures can also exhibit an interlayer exchange coupling (IEC), when prepared with a high crystalline quality. Here, we present a discrete layer-by-layer magnetic switching in Fe/MgO(001) superlattices of 10 repetitions with an antiferromagnetic IEC [1]. The structures were prepared via sputtering and the crystalline quality and layering was investigated via x-ray diffraction and reflectivity, respectively as well as via transmission electron microscopy. The magnetic properties were studied via the longitudinal magneto-optical Kerr effect as well as with polarized neutron reflectivity.

[1] R. Moubah, F. Magnus, T. Warnatz, et al. Phys. Rev. Applied 5, 044011 (2016).

MA 68.24 Fri 9:30 P2-OG4

Magnetic anisotropy in Ni-PtMnGa — •Luana Caron[1], Sanjay Singh[1], Biswanath Dutta[3], Jayita Nayak[1], Sunil W. D'Souza[1], Riccardo Cabassi[2], Fulvio Bolzoni[2], Simone Fabbrici[2], Franca Albertini[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]IMEM-CNR, Parma, Italy — [3]Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany

Magnetic shape memory in Heusler alloys attracts a great deal of interest due to their possible applications as actuators. In materials such as Ni_2MnGa[1] strong magneto crystalline anisotropy(MCA) gives rise to large magnetic field induced strain (MFIS) at low applied fields which greatly exceed those induced by temperature in non-magnetic shape memory alloys. Practical application of the large MFIS in Ni_2MnGa is hindered by a low martensitic transition temperature (T_M) and poor mechanical stability, which still remain a challenge. Within this scope, Pt substituted Ni_2MnGa alloys have been put forward as promising MFIS materials for applications. Pt substitution elevates T_M[2,3], making it possible to use these materials in room temperature applications. However, practical MFIS applications depend on T_M as well as on the large MCA. In this work we present a detailed study of the MCA in $Ni_{2-x}Pt_xMnGa$ with x $\leq$ 0.25 using ab initio calculations and the singular point detection technique.[4]

[1]K. Ullakko et al., Appl. Phys. Lett. 69, 1966 (1996); [2]Y. Kishi et al., Mater. Sci. Eng.: A 378, 361 (2004); [3]S. Singh et al., Phys. Rev. B 93, 134102 (2016); [4]G. Asti et al., J. Appl. Phys. 45, 3600 (1974).

MA 68.25 Fri 9:30 P2-OG4

Probing multi-caloric effects (magneto-, baro-, and elasto-) in all-d-metal magnetic Heusler shape memory alloys — •Enke Liu[1,2], Zhiyang Wei[2], Catalina Salazar Mejia[3], Mahdiyeh Ghorbani-Zavareh[1], Zhaosheng Wang[3], Jian Liu[4], Xuekui Xi[2], Wenhong Wang[2], Guangheng Wu[2], Xixiang Zhang[5], and Claudia Felser[1] — [1]Max-Planck Institute for Chemical Physics of Solids, Dresden, Germany. — [2]Insititute of Physics, Chinese Academy of Sciences, Beijing, China. — [3]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany. — [4]Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo, China. — [5]King Abdullah University of Science and Technology, Thuwal, Saudi Arabia.

Caloric effects, driven by different external fields in phase transitions, are drawing increasing attention from solid-state cooling in very recent years. In this work, I will show the multi-caloric effects in a new family of magnetic shape memory alloys of all-d-metal Heusler Ni(Co)-Mn-Ti under different external fields of hydrostatic pressure, axial stress, and pulsed high magnetic field. A pressure driving efficiency of dTt/dp = 56 K/GPa was obtained based on the large volume change of $\Delta\omega$ = 2 percent during the hydrostatic pressure, leading to a large $\Delta\omega$|dTt/dp|-1 of 0.036 percent K GPa-1. Large adiabatic temperatures of 10 K and 9 K were, respectively, observed during the axial loading and the pulsed magnetic fields. Large multi-caloric effects can be gained in the all-d-metal Heusler Ni(Co)-Mn-Ti based on the strong magnetostructural coupling.

MA 68.26 Fri 9:30 P2-OG4

Magnetic vortex core pinning and its influence on core gyration detection by STM — •Marvin Knol — II. Physikalisches Institut B, RWTH Aachen University

A magnetic vortex is the simplest non-trivial magnetic order of thin magnetic platelets with low magnetic anisotropy. The center of this chiral magnetic structure features an out of plane magnetic moment called the vortex core. We use external magnetic fields to manipulate the core within Fe islands prepared in UHV on W(110) probing it via spin polarized STM [1]. As expected, the vortex core is squeezed by an oppositely oriented out-of-plane field up to 1.6 T and shifted by an in-plane field. Moreover, we find Barkhausen like jumps [2] in the magnetization during in-plane field sweeps when the vortex core is additionally squeezed by an out-of-plane field. We attribute the jumps to pinning most likely at remaining surface adsorbates.

Micromagnetic simulations [3] reveal that the vortex core gyration is only excitable by spin polarized STM, if a resonant high frequency current is applied to a tip of canted magnetization with respect to the vortex core and the core is additionally squeezed. Thus, overcoming the pinning of the squeezed core is mandatory for dynamic experiments.

[1] A. Wachowiak et al., Science 298, 577*580 (2002)
[2] R. L. Compton et al., Phys. Rev. Lett. 97, 137202 (2006)
[3] A. Vansteenkiste et al., AIP Adv. 4, 107133 (2014)

MA 68.27 Fri 9:30 P2-OG4

Magnetic band gap opening at the Dirac point in Mn-doped bismuth telluride — •Partha S. Mandal[1], Emile Rienks[1,2,3], Jaime Sánchez-Barriga[1], Andrei Varykhalov[1], Gunther Springholz[3], Valentine Volobuiev[4,5], and Günther Bauer[3] — [1]Helmholtz-Zentrum Berlin, Albert-Einsteins-Str. 15, 12489 Berlin — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, 01069 Dresden — [3]Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden — [4]Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität, 4040 Linz, Austria — [5]Kharkiv Polytechnic Institute, 61002 Kharkiv, Ukraine

We have recently shown that the large (approx. 100 meV) band gap at the Dirac point of Mn-doped bismuth selenide is not of magnetic origin [1]. Here we demonstrate by angle-resolved photoemission a magnetic band gap of about 25 meV in Mn-doped bismuth telluride at 1 K. In contrast, Mn-doped bismuth selenide does not show any magnetic band gap when cooled below its Curie temperature of about 6 K. The different behavior of the two systems will be explained in the presentation.

[1] J. Sánchez-Barriga, A. Varykhalov, G. Springholz, H. Steiner, R. Kirchschlager, G. Bauer, O. Caha, E. Schierle, E. Weschke, A. A. Ünal, S. Valencia, M. Dunst, J. Braun, H. Ebert, J. Minár, E. Golias, L.V. Yashina, A. Ney, V. Holý, O. Rader, Nat. Commun. 7, 10559 (2016).

MA 68.28 Fri 9:30 P2-OG4

Dry-coating of magnetocaloric La(Fe,Si)13 — •Madhuri Wuppulluri, Snehajyoti Saha, Juliane Thielsch, Samuel Grasemann, and Anja Waske — IFW Dresden

La(Fe,Si)13 is a promising magnetocaloric material class with Curie transition near room temperature. However, forming regenerator beds for magnetocaloric cooling applications is challenging due to its poor mechanical strength. Pure elemental metal coating on La-Fe-Si results in higher mechanical strength, thermal conduction and reduces corrosion. Here dry coating of LaFeSi-based particles is presented and compared to that of ball milling. Magnetic and structural characterization of the coated powders is discussed.

This work was supported by the Eleonore Trefftz Programme for Visiting Women Professors of the TU Dresden, the DAAD Sandwich Model Scholarships for Master's Students of the IITs and IIMs, and the German Federal Ministry of Economics and Energy (BMWi) within the *Verbundvorhaben: EnOB: SOMAK * Solare magnetische Klimatisierung von Gebäuden.

MA 69: Frontiers of Electronic-Structure Theory: New Concepts and Developments in Density Functional Theory and Beyond

Time: Friday 10:30–13:00 Location: HSZ 02

Invited Talk MA 69.1 Fri 10:30 HSZ 02
Going Beyond Conventional Functionals with Scaling Corrections and Pairing Fluctuations — •Weitao Yang — Duke University

Fractional fractional charges and fractional spins provide a clear analysis of the errors of commonly used functionals. We developed a scaling correction scheme by imposing the Perdew-Parr-Levy- Balduz linearity condition. Our novel scheme leads to the significantly improved description of dissociating molecules, transition-state species, and charge-transfer systems. Within many-electron theory, we have formulated the ground-state exchange-correlation energy in terms of pairing matrix linear fluctuations, opening new a channel for density functional approximations. This method has many highly desirable properties. It has minimal delocalization error with a nearly linear energy behavior for systems with fractional charges, describes van der Waals interactions similarly and thermodynamic properties significantly better than the conventional RPA, and captures the energy derivative discontinuity in strongly correlated systems. We also adopted pp-RPA to approximate the pairing matrix fluctuation and then determine excitation energies by the differences of two-electron addition/removal energies. This approach captures all types of interesting excitations: single and double excitations are described accurately, Rydberg excitations are in good agreement with experimental data and CT excitations display correct 1/R dependence.

Invited Talk MA 69.2 Fri 11:00 HSZ 02
Multi-reference density functional theory — •Andreas Savin — Laboratoire de Chimie Théorique, CNRS and UPMC, Univ. Paris VI, Sorbonne University, Paris, France

It is sometimes said that there is no multi-reference density functional theory. The talk presents a personal viewpoint, and will focus on the following points. 1) There are many ways to introduce multi-determinant wave functions into density functional theory. 2) Several variants have been successfully explored. 3) Difficulties inherent to approximations (both for wave functions and density functionals) persist, but can be attenuated.

Invited Talk MA 69.3 Fri 11:30 HSZ 02
Density functionals from machine learning — •Kieron Burke — UC Irvine

Machine learning is spreading to all aspects of our lives. A particular method, kernel ridge regression, has proven very useful for fitting and interpolating in high-dimensional spaces.

Several years ago, in collaboration with the group of Klaus-Robert Muller in computer science at TU Berlin, we demonstrated how to construct a machine-learned density functional on a simple toy problem, non-interacting fermions in a box. We showed both its successes and limitations. We have continued to develop this method (PRL, 2012).

I will report on two recent works. In the first (arXiv:1609.02815), we construct the non-interacting kinetic energy functional for small molecules in 3D using a basis. We avoid the challenge of finding functional derivatives by learning the potential to density map directly, thereby bypassing the need to solve the Kohn-Sham equations.

In the second, we learn the interacting functional directly for the first time. In 1D, we model chains of H atoms of different length, and learn F[n] itself, from highly accurate DMRG calculations. With a novel choice of basis for the densities, we are able to learn the functional to chemical accuracy in the thermodynamic limit (arXiv:1609.03705).

Invited Talk MA 69.4 Fri 12:00 HSZ 02
Taming Memory-Dependence in Time-Dependent Density Functional Theory — •Neepa Maitra — Hunter College of the City University of New York

The exact exchange-correlation functional of time-dependent density functional theory (TDDFT) is known to depend on the history of the densities and the initial states, a dependence which is ignored in almost all of the calculations today that use an adiabatic approximation. The lack of this dependence can sometimes lead to drastically incorrect predictions of the dynamics, as has been shown in several examples recently. We present here a new approach to developing functional approximations that breaks free of the adiabatic approximation, and test the resulting approximations on a number of model systems.

Invited Talk MA 69.5 Fri 12:30 HSZ 02
Quantum Embedding Theories — •Fred Manby — School of Chemistry, University of Bristol, Cantock's Close, Bristol, BS8 1TS, UK

Issues of accuracy in density functional theory can be addressed by making more accurate methods (like coupled-cluster theory) more efficient; or by making density functional approximations more accurate. Efforts in both directions are underway in our group, but in this talk I will focus on a third possibility, namely the development of quantum-mechnical multiscale models that enable the use of a high-accuracy method in a small, physically important region coupled to density-functional theory (or other low-cost methods) to describe the molecular environment.