Magnetism Division
Fachverband Magnetismus (MA)

Celebrating its 60th anniversary (founded 1956)

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Overview of Invited Talks and Sessions

(Lecture rooms H31, H32, H33, H34; Poster B1)

Thyssen-Krupp Electrical Steel Dissertationspreis

Monday 15:00–17:00 H32
Four candidates will compete for the prize. Please attend!
For details see http://www.dpg-physik.de/dpg/gliederung/fv/ma/dissertationspreis.html

General Meeting of the Magnetism Division (Fachverband Magnetismus)

Thursday 18:30–19:30 H32
All members of the Magnetism Section are requested to attend!

Tutorial: Spin Hall Effect and Spin-orbit Torques

MA 1.1	Sun	16:00–16:45	H17	**Introduction to Spin Hall Effect** — •Christian Back
MA 1.2	Sun	17:00–17:45	H17	**Magnetisation of ferromagnetic nanostructures manipulated by spin-orbit torques** — •Stefania Pizzini
MA 1.3	Sun	17:45–18:30	H17	**Spin Hall effect and spin-orbit torque from material-specific theory** — •Yuriy Mokrousov

Symposium "Quantum Signatures in Magnetism (SYQS)"

See SYQS for the abstracts of the symposium.

SYQS 1.1	Wed	15:00–15:30	H1	**Magnonic macroscopic quantum states and supercurrents** — •Burkard Hillebrands, Dmytro A. Bozhko, Alexander A. Serga
SYQS 1.2	Wed	15:30–16:00	H1	**Elementary excitations of magnetic insulators and its heterostructures with metals** — •Gerrit Bauer
SYQS 1.3	Wed	16:00–16:30	H1	**Cavity Spintronics** — •Can-Ming Hu
SYQS 1.4	Wed	16:45–17:15	H1	**Hybrid Quantum Systems - Coupling Color Centers to Superconducting Cavities** — •Johannes Majer
SYQS 1.5	Wed	17:15–17:45	H1	**Quantum enhanced sensing with single spins in diamond** — •Fedor Jelezko

Invited Talks

MA 5.1	Mon	9:30–10:00	H34	**Néel-type skyrmions in a type-I multiferroic compound** — •Istvan Kezsmarki
MA 30.1	Wed	9:30–10:00	H33	**Spin-orbit torques and charge pumping in crystalline magnets** — •Chiara Ciccarelli

MA 46.1	Thu	15:00–15:30	H33	**Advanced magneto-optical microscopy: Magnetoelectric sensors, spin-waves, and beyond** — •Jeffrey McCord
MA 54.1	Fri	9:30–10:00	H34	**Itinerant Magnetism in the Parent Iron-Based Superconductors: hidden frustration, nematic transitions, and spin-orbit coupling** — •Ilya Eremin

Focus Session “Magnetism as seen by neutrons”

MA 14.1	Tue	9:30–10:00	H32	**Breakthrough neutron spectroscopy for quantum magnetism** — •Andrey Zheludev
MA 14.2	Tue	10:00–10:30	H32	**Topological magnetism as seen by neutrons** — •Roderich Moessner
MA 14.3	Tue	10:45–11:15	H32	**Magnetism at heterostructures and interfaces** — •Hans Boschker
MA 14.4	Tue	11:15–11:45	H32	**Vortex matter: from superconductivity to skyrmions** — •Sebastian Mühlbauer
MA 14.5	Tue	11:45–12:15	H32	**Neutron spectroscopy – Collective excitations in (un)conventional superconductors** — •Jitae Park

Focus Session “Terahertz radiation and magnetism”

MA 40.1	Thu	9:30–10:00	H32	**Sub-cycle terahertz electronics and magnonics: control and nanoscopy** — •Rupert Huber
MA 40.2	Thu	10:00–10:30	H32	**Probing and controlling ultrafast magnetism with terahertz electromagnetic pulses** — •Tobias Kampfrath
MA 40.3	Thu	10:45–11:15	H32	**THz Spintronics: Magnetotransport and Magnonics** — •Zuanming Jin
MA 40.4	Thu	11:15–11:45	H32	**Precessional spin motion and magnetization quenching induced by intense Terahertz pulses** — •Christoph Hauri

Focus Session “Disorder Engineering as a Tool for Materials Science”

MA 45.1	Thu	15:00–15:30	H32	**Charge carrier scattering and electronic transport in graphene** — •Mikhail Katsnelson
MA 45.2	Thu	15:30–16:00	H32	**Electrons in disordered systems: extensions to the coherent potential approximation for short- and long-ranged order effects** — •Julie Staunton
MA 45.3	Thu	16:15–16:45	H32	**Percolation and other models for quenched disorder in materials, and some consequences of this disorder on physical properties.** — •Kurt Binder
MA 45.4	Thu	16:45–17:15	H32	**The Impact of Disorder on Transport in crystalline Phase Change Materials** — •Matthias Wuttig

Focus Session "Ultrafast spin currents for spin-orbitronics: from metals to topological insulators"

MA 52.1	Fri	9:30–10:00	H32	**Experimental separation of various mechanisms leading to laser-pulse-induced magnetization precession in (Ga,Mn)As** — •Petr Nemec
MA 52.2	Fri	10:00–10:30	H32	**Ultrafast photocurrents and quantized conductance in 3D topological insulators** — •Alexander Holleitner
MA 52.3	Fri	10:45–11:15	H32	**Real-time time-dependent DFT for spin dynamics in magnets** — •Stefano Sanvito
MA 52.4	Fri	11:15–11:45	H32	**Spin transport and spin-orbit interaction at terahertz frequencies: spectroscopy and applications** — •Tom Seifert
MA 52.5	Fri	11:45–12:15	H32	**Driving currents by magnetization dynamics in systems with broken inversion symmetry** — •Frank Freimuth

Sessions

MA 1.1–1.3	Sun	16:00–18:30	H17	**Tutorial: Spin Hall Effect and Spin-Orbit Torques**
MA 2.1–2.6	Mon	9:30–11:00	H31	**Magnetic Materials I**
MA 3.1–3.9	Mon	9:30–12:00	H32	**Micro- and nanostructured Materials**
MA 4.1–4.9	Mon	9:30–12:00	H33	**Bio- und molekularer Magnetismus**
MA 5.1–5.13	Mon	9:30–13:30	H34	**Spin Textures and magnetic Phase Transitions**
MA 6.1–6.11	Mon	9:45–13:00	H22	**Transport: Quantum Coherence and Quantum Information Systems - Experiment (Joint session of HL, MA and TT organized by TT)**
MA 7.1–7.10	Mon	15:00–17:45	H18	**Transport: Topological Insulators - 2D (Joint session of DS, HL, MA, O and TT organized by TT)**
MA 8.1–8.9	Mon	15:00–17:30	S052	**Magnetic Surface Excitations**
MA 9.1–9.12	Mon	15:00–18:15	H31	**Spincaloric Transport (jointly with TT)**
MA 10	Mon	15:00–17:00	H32	**Thyssen-Krupp Electrical Steel Ph. D. Thesis Award (Dissertationspreis)**
MA 11.1–11.10	Mon	15:00–17:45	H33	**Magnetic Thin Films I**
MA 12.1–12.12	Tue	9:30–12:45	H22	**Transport: Quantum Coherence and Quantum Information Systems - Theory 1 (Joint session of HL, MA and TT organized by TT)**
MA 13.1–13.7	Tue	9:30–11:15	H31	**Magnetic Materials II**
MA 14.1–14.5	Tue	9:30–12:15	H32	**Focus: Magnetism as seen by neutrons**
MA 15.1–15.9	Tue	9:30–12:00	H33	**Magnetic Thin Films II**
MA 16.1–16.11	Tue	9:30–12:30	H34	**Magnetization and Demagnetization Dynamics I**
MA 17.1–17.89	Tue	9:30–12:30	Poster B1	**Poster Session I**
MA 18.1–18.4	Tue	10:15–11:45	H53	**Topical session: Caloric Effects in ferroic materials I - Magnetocalorics**
MA 19.1–19.7	Tue	11:30–13:15	H31	**Magnetic Materials III**
MA 20.1–20.6	Tue	14:00–15:45	H18	**Transport: Topological Insulators - 3D (Joint session of DS, HL, MA, O and TT organized by TT)**
MA 21.1–21.4	Tue	14:00–15:00	H22	**Transport: Quantum Coherence and Quantum Information Systems - Theory 2 (Joint session of HL, MA and TT organized by TT)**
MA 22.1–22.5	Tue	14:00–15:15	H31	**Magnetic Semiconductors (jointly with HL)**
MA 23.1–23.6	Tue	14:00–15:30	H32	**Magnetic Materials and Caloric Effects**
MA 24.1–24.10	Tue	18:15–20:30	Poster E	**Electronic Structure: Surface Magnetism and Spin Phenomena**
MA 25.1–25.13	Wed	9:30–13:15	H22	**Transport: Graphene (Joint session of DS, DY, HL, MA, O and TT organized by TT)**
MA 26.1–26.13	Wed	9:30–13:15	H22	**Transport: Graphene (Joint session of DS, DY, HL, MA, O and TT organized by TT)**
MA 27.1–27.7	Wed	9:30–12:50	H25	**Focus Session: Skyrmions meet Multiferroicity**
MA 28.1–28.9	Wed	9:30–12:00	H31	**Surface Magnetism I (jointly with O)**
MA 29.1–29.10	Wed	9:30–12:15	H32	**Spintronics (incl. quantum dynamics) (jointly with HL, TT)**
MA 30.1–30.12	Wed	9:30–13:15	H33	**Spin-Torque Phenomena**
MA 31.1–31.12	Wed	9:30–12:45	H34	**Magnetization and Demagnetization Dynamics II**
MA 32.1–32.5	Wed	15:00–17:00	H4	**Scanning Probe Microsocopy and Spin Phenomena**
MA 33.1–33.9	Wed	15:00–17:30	H31	**Surface Magnetism II (jointly with O)**
MA 34.1–34.10	Wed	15:00–17:45	H32	**Topological Insulators (jointly with DS, HL, O, TT)**
MA 35.1–35.12	Wed	15:00–18:15	H33	**Spin dependent Transport Phenomena**
MA 36.1–36.12	Wed	15:00–18:15	H34	**Magnetization and Demagnetization Dynamics III**
MA 37.1–37.13	Thu	9:30–13:00	H23	**Transport: Molecular Electronics and Photonics 1 (Joint session of CPP, DS, HL, MA, O and TT organized by TT)**
MA 38.1–38.9	Thu	9:30–12:50	H25	**Multiferroics I (DF with MA)**
MA 39.1–39.14	Thu	9:30–13:15	H31	**Magnetic Particles**
MA 40.1–40.4	Thu	9:30–11:45	H32	**Focus: Terahertz radiation and magnetism**
MA 41.1–41.9	Thu	9:30–12:00	H33	**Magnetic Coupling Phenomena**
MA 42.1–42.11	Thu	9:30–12:30	H34	**Magnetic Heuslers, Half-Metals and Oxides (jointly with TT)**

MA 43.1–43.4	Thu	15:00–16:00	H23	**Transport: Molecular Electronics and Photonics 2 (Joint session of CPP, DS, HL, MA, O and TT organized by TT)**
MA 44.1–44.11	Thu	15:00–18:00	H31	**Spininjection / Spin currents in heterostructures**
MA 45.1–45.4	Thu	15:00–17:15	H32	**Focus: Disorder Engineering as a Tool for Material Science**
MA 46.1–46.11	Thu	15:00–18:30	H33	**Magnetic Measurement Methods**
MA 47.1–47.9	Thu	15:00–17:30	H34	**Multiferroics II (jointly with DF, KR, TT)**
MA 48.1–48.72	Thu	15:00–18:00	Poster B1	**Poster Session II**
MA 49.1–49.7	Thu	16:15–18:30	H23	**Transport: Spintronics and Magnetotransport (Joint session of DS, HL, MA and TT organized by TT)**
MA 50	Thu	18:30–19:30	H32	**General Meeting of the Magnetism Division (Fachverband Magnetismus)**
MA 51.1–51.6	Fri	9:30–11:30	H13	**Magnetic Semiconductors**
MA 52.1–52.5	Fri	9:30–12:15	H32	**Focus: Ultrafast spin currents for spin-orbitronics: from metals to topological insulators**
MA 53.1–53.8	Fri	9:30–11:45	H33	**Magnetic Scattering Methods**
MA 54.1–54.11	Fri	9:30–13:00	H34	**Electron Theory of Magnetism and Micromagnetic Simulations**

Symposium "Caloric Effects in Ferroic Materials (SYCE)"

See SYCE for the abstracts of the symposium.

SYCE 1.1	Mon	15:00–15:30	H1	**Multicaloric effects in metamagnetic Heusler materials** — •Antoni Planes
SYCE 1.2	Mon	15:30–16:00	H1	**Multicaloric effect in biological systems: a case of nerve action** — •Matjaz Valant, Lawrence J. Dunne, Anna-Karin Axelsson, Florian Le Goupil, George Manos
SYCE 1.3	Mon	16:00–16:30	H1	**Optimizing the electrocaloric effect by first-principles simulations: The role of strain and defects** — •Anna Grünebohm
SYCE 1.4	Mon	16:45–17:15	H1	**Giant inverse barocaloric effects in ferrielectric ammonium sulphate** — Pol Lloveras, Enric Stern-Taulats, Maria Barrio, Josep Lluis Tamarit, Sam Crossley, Wei Li, Vladimir Pomjakushin, Antoni Planes, Lluis Mañosa, Neil Mathur, •Xavier Moya
SYCE 1.5	Mon	17:15–17:45	H1	**TiNiCu-based thin films for elastocaloric cooling** — •Eckhard Quandt, Christoph Chluba

Symposium "Topological Insulators: Status Quo and Future Directions (SYTI)"

See SYTI for the abstracts of the symposium.

SYTI 1.1	Wed	9:30–10:10	H1	**Topological insulators and topological superconductors** — •Shoucheng Zhang
SYTI 1.2	Wed	10:10–10:50	H1	**Three-dimensional topological insulators and superconductors** — •Yoichi Ando
SYTI 1.3	Wed	10:50–11:30	H1	**Interplay of magnetic and electronic states in pyrochlore iridates** — •Leon Balents
SYTI 1.4	Wed	11:40–12:20	H1	**Magnetic imaging of edge states** — •Kathryn Moler
SYTI 1.5	Wed	12:20–13:00	H1	**Sub-nm wide edge states at the dark side of a weak topological insulator** — •Markus Morgenstern

Symposium "Frontiers of Electronic Structure Theory: Focus on Topology and Transport (SYES)"

See SYES for the abstracts of the symposium.

SYES 1.1	Fri	9:30–10:00	H1	**Intrinsic Transport Coefficients and Momentum Space Berry Curvatures** — •Allan H MacDonald
SYES 1.2	Fri	10:00–10:30	H1	**Berry phase linked spin-orbit torques in Ferromagnetic and Antiferromagnetic systems** — •Jairo Sinova

SYES 1.3	Fri	10:30–11:00	H1	**Transport in Topological Insulators and Topological Superconductors: In Search of Majorana Fermions** — •Ewelina Hankiewicz
SYES 1.4	Fri	11:15–11:45	H1	**Engineering Topological Quantum States: From 1D to 2D.** — •Jelena Klinovaja
SYES 1.5	Fri	11:45–12:15	H1	**Skyrmions – Topological magnetization solitons for future spintronics** — •Stefan Blügel

MA 1: Tutorial: Spin Hall Effect and Spin-Orbit Torques

Organizers: Karin Everschor-Sitte and Matthias Sitte (Johannes Gutenberg Universität Mainz)

In spintronics, magnetic textures are manipulated by spin-polarized currents. A traditional way to obtain a spin-polarized current is by sending an electric current through a ferromagnet. A different option is to exploit the spin Hall effect which is the generation of a spin current perpendicular to an applied charge current. This tutorial provides an introduction into the field of spin Hall effect and spin-orbit torques.

Time: Sunday 16:00–18:30 Location: H17

Tutorial MA 1.1 Sun 16:00 H17

Introduction to Spin Hall Effect — •Christian Back — University of Regensburg, Regensburg, Germany

We give here an overview of the spin Hall effect. Since its discovery over a decade ago the spin Hall effect has been one of the most researched areas of spintronics, with multiple unexpected new phenomena arising from its studies. Its origins, both intrinsic and extrinsic, have been studied both theoretically and experimentally, giving us now a rich picture of this phenomena which is present in many branches of spintronics. It is connected of course to the anomalous Hall effect, but in recent years it is understood to be linked closely with magnetization dynamics as well as inverse spin Galvanic effect. The fields of Topological Insulators also arose from the spin Hall effect in the limit if large spin-orbit coupling. We summarise the recent review written on the subject that covers most of the developments over the last decade.

15 min. break

Tutorial MA 1.2 Sun 17:00 H17

Magnetisation of ferromagnetic nanostructures manipulated by spin-orbit torques — •Stefania Pizzini — Institut Néel, CNRS, Grenoble, France

It has been shown recently that spin-orbit torques (SOT) associated to the spin-Hall effect, generated by the flow of an electrical current in the plane of a ferromagnetic/heavy metal bilayer, can be used as an efficient way to manipulate the magnetisation of nanostructures with broken inversion asymmety.

After an introduction to the microscopic origins of the SOT, I will give a review of recent experimental work showing the use of this mechanism to obtain both deterministic switching of nanosized magnets, and efficient propagation of domain walls in nanotracks consisting of ultrathin ferromagnetic layers with perpendicular magnetic anisotropy and strong Dzyaloshinskii-Moriya interaction.

Tutorial MA 1.3 Sun 17:45 H17

Spin Hall effect and spin-orbit torque from material-specific theory — •Yuriy Mokrousov — Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

The phenomena of spin Hall effect (SHE) in magnetic and non-magnetic materials, and spin-orbit torque (SOT) in magnetic materials with broken inversion symmetry have become major sources of intensive interest for both theoreticians and experimentalists, owing to their importance for future technology based on relativistic effects. In my talk I will present an overview of recent progress in our understanding and description of the SHE and SOT based on the material-specific first principles theory. My particular focus will be both on the intrinsic Berry phase and impurity-driven origins of the SHE and its anisotropy in paramagnets, ferromagnets and antiferromagnets. I will then review the various origins of the SOT in magnetic bilayers, show how the SOT can be understood based on the non-trivial topology of the electronic bands, and outline the relation between the SOT and the spin currents originated in the non-magnetic substrate.

MA 2: Magnetic Materials I

Time: Monday 9:30–11:00 Location: H31

MA 2.1 Mon 9:30 H31

Analysis of Local Magnetisation, Composition, and *in Situ* Magnetization Reversal in (Dy,Nd)-Fe-B Core-Shell Sintered Magnets — •Tim Helbig[1], Konrad Löwe[1], and Oliver Gutfleisch[1,2] — [1]TU Darmstadt, Functional Materials — [2]Fraunhofer IWKS Hanau, Germany

One approach to reduce the amount of expensive heavy rare earth elements (RE), such as Dy or Tb, in permanent magnets is to design the grain boundaries of modern high performance NdFeB-type magnets. Their grains consist of a heavy RE rich shell and a $Nd_2Fe_{14}B$ core. Heavy REs are needed to provide high coercivity especially at elevated temperatures, they reduce however the total magnetic moment at the same time. The idea of the shell structures is to use as little Dy as necessary to improve the coercivity of the entire magnet by only concentrating Dy at the "weak point" i.e. the grain boundary. In this work, a core-shell structured (Dy,Nd)-Fe-B sintered magnet was produced through a novel experimental technique involving blending of powders with different compositions and grain sizes and analysed by Scanning Electron Microscope (SEM), Magnetic Force Microscopy (MFM) and Kerr microscopy. It was possible to correlate all used characterisation methods on the same specific area and match chemical composition with local magnetisation. Further, *in situ* magnetization reversal using MFM and Kerr with externally applied magnetic fields were employed.

MA 2.2 Mon 9:45 H31

Magnetic neutron scattering on textured and isotropic Nd-Fe-B-based nanocomposites — •Raoul Weber[1], Andreas Michels[1], Élio Alberto Périgo[1], Ivan Titov[1], Denis Mettus[1], Joachim Kohlbrecher[2], Masao Yano[3], Akira Kato[3], Masaaki Ito[4], and Kiyonori Suzuki[5] — [1]Physics and Materials Science Research Unit, University of Luxembourg — [2]Paul Scherrer Institut, Switzerland — [3]Toyota Motor Corporation, Japan — [4]Institut Néel, Grenoble, France — [5]Monash University, Clayton, Australia

Nd-Fe-B nanocomposite permanent magnets, which consist of exchange-coupled hard ($Nd_2Fe_{14}B$) and soft ($\alpha-$Fe) magnetic phases, are of potential interest for electronic devices due to their preeminent magnetic properties such as high remanence and magnetic energy product. Based on recent density-functional-theory calculations which predict a dependency of the exchange coupling on the crystallographic orientation at the interface between $Nd_2Fe_{14}B$ and $\alpha-$Fe (ferromagnetic $\leftrightarrow$ antiferromagnetic), we have carried out a comparative study of the magnetic microstructure of textured and isotropic nanocrystalline $Nd_2Fe_{14}B/\alpha-$Fe by means of magnetic-field-dependent small-angle neutron scattering.

MA 2.3 Mon 10:00 H31

Influence of Ce and Co substitution on the magnetocrystalline anisotropy of $(NdCe)_2(FeCo)_{14}B$ single crystals — •Bahar Fayyazi, Konstantin Skokov, Christoph Schwöbel, and Oliver Gutfleisch — Material Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

Due to recent pressures on the availability and cost of rare-earth (RE) metals, especially for Nd and Dy which are essential for high performance $Nd_2Fe_{14}B$ -type permanent magnets, it is a priority to develop materials that rely less on scarce RE-elements. Cerium is the most abundant and low cost rare-earth element without significant supply restrictions. At the same time, $Nd_2Fe_{14}B$ and $Ce_2Fe_{14}B$ adopt the same crystal structure and many research efforts around the world are directed toward substitution of Nd, Tb and Dy in $Nd_2Fe_{14}B$ -type permanent magnets by Ce (so-called rare balance magnets) without significant concurrent reduction of remanent magnetization, coercivity and Curie temperature, what, in turn, is a really challenging task. In this work, we report on magnetocrystalline anisotropy and spontaneous magnetization of $(NdCe)_2(FeCo)_{14}B$ single crystals. Anisotropy constants K_1, K_2 and K_3 were exstracted from experimental field dependences of magnetization measured along [001] [100] and [110] crystallographic directions. We also explored how the change of the composition affects effective magnetic moment, temperature of spin-reorientation transition and Curie temperature.

MA 2.4 Mon 10:15 H31

Magnetic properties of hard magnetic (Fe,Cr)$_3$Sn$_2$ intermetallic compounds — •Dagmar Goll, Ralf Loeffler, Johannes Herbst, Christoph Frey, Susanne Goeb, Tvtrko Grubesa, Dominic Hohs, Andreas Kopp, Ulrich Pflanz, Roland Stein, and Gerhard Schneider — Aalen University, Materials Research Institute (IMFAA), Aalen, Germany

Novel magnetic materials filling the wide-open gap between cost-efficient hard ferrites and expensive high-performance Fe-Nd-B are desirable for efficient energy converters. By experimental bulk high-throughput screening Fe-Sn-X, rare earth free $(Fe,Cr)_3Sn_2$ with high potential as new hard magnetic compound has been discovered. For fabricating the compound in large amounts, a cycle procedure (grinding-pelletizing-annealing) has been used. By quantitative microscopy and magnetometry promising intrinsic magnetic properties $J_S \approx 0.9$ T (saturation polarization), $K_1 \approx 1.7$ MJ/m^3 (anisotropy constant and $T_C \approx 612$ K (Curie temperature) have been found with K_1 increasing with temperature. According to X-ray diffraction the crystal structure of $(Fe,Cr)_3Sn_2$ is modified compared to Fe_3Sn_2 (*project supported by BMBF*).

MA 2.5 Mon 10:30 H31

Investigation of low temperature phase MnBi with temperature dependent first-order reversal curve measurements. — •Shreyas Muralidhar[1,2], Joachim Gräfe[1], Yu-Chun Chen[1], Helmut Kronmüller[1], Gisela Schütz[1], and Eberhard Goering[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart — [2]Universität Stuttgart

The rare earth free intermetallic compound MnBi in the low temperature phase (LTP) is a permanent magnet with sufficiently high energy product (BH)max for high temperature applications. At 500K LTP-MnBi has the highest coercivity. A striking property of the LTP-MnBi is the positive temperature coefficient of coercivity. To understand the behavior of micro coercivities and interaction field leading to the effective behavior of the coercivity, a study of the First-Order Reversal Curve (FORC) diagrams was required. A detailed FORC analysis has been performed for the first time on LTP-MnBi, at various temperatures. This gave an insight into the influence of microstructural properties on the magnetic properties of the hard magnetic system. The temperature dependent FORC analysis indicated a unique variation of the distribution from narrow-broad-narrow along the coercivity axis. A semi-quantitative explanation for the behavior of the micro-coercivities can be provided utilizing the structural information and its influence on the nucleation field of the material. A better understanding of the coercivity behavior linked with the microstructure helps to tailor the synthesis methods to obtain high performance permanent magnets.

MA 2.6 Mon 10:45 H31

Searching room temperature martensite phases of Fe-Mn-Ga — Johannes Kroder, •Semih Ener, Konstantin P. Skokov, and Oliver Gutfleisch — Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

For the search of new permanent magnet materials a bulk high-throughput method is needed. One possible candidate for bulk high-throughput screening is simple and low-cost reactive crucible melting method. The tetragonal phases of the Heusler alloys may show potential as a permanent magnet material. In this work we successfully applied the reactive crucible melting method to the Ni-Mn-Ga and Fe-Mn-Ga ternary Heusler systems. The room temperature ternary phase diagram of Fe-Mn-Ga is reported for a specific composition region. The most interesting observed hard magnetic material is $Mn_{38.5}Fe_{32.5}Ga_{29}$ with the remanent magnetization of 20 Am^{2}kg^{-1} and a coercivity of 0.33 T. Observed relatively high coercivity (without any exchange bias effect) shows the possibility of using the Heusler-type materials as hard magnetic materials.

MA 3: Micro- and nanostructured Materials

Time: Monday 9:30–12:00 Location: H32

MA 3.1 Mon 9:30 H32

Mn$_x$Ga$_{1-x}$ Thin Films and Nanodots with High Coercivity and Perpendicular Magnetic Anisotropy — •Julie Karel[1], Francesca Casoli[2], Pierpaolo Lupo[2], Lucia Nasi[2], Federica Celegato[3], Simone Fabbrici[2,4], Lara Righi[2,5], Paola Tiberto[3], Franca Albertini[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]IMEM-CNR, Parma, Italy — [3]INRIM, Electromagnetism Division, Turin, Italy — [4]MIST E-R Laboratory, Bologna, Italy — [5]Dipartimento di Chimica, Universita di Parma, Parma, Italy

Tetragonal Mn_xGa_{1-x} ($x = 0.70, 0.75$) thin films exhibit perpendicular magnetic anisotropy with coercive fields between 1-2 T. Transmission electron microscopy (TEM) and X-ray diffraction (XRD) reveal that 40nm samples grown at $300-350°$C lead to films with the tetragonal c-axis oriented primarily perpendicular to the film plane but with some fraction of the sample exhibiting the c-axis in the film plane. Growth at 300°C with a reduced thickness or Mn concentration significantly decreases the tetragonal c-axis in the film plane. A $Mn_{0.7}Ga_{0.3}$ epitaxial thin film with perpendicular magnetic anisotropy and a large coercivity was patterned into nanodots using a self-assembly nanolithography procedure. The resulting nanodots retain the properties of the original film. Our results suggest this lithography procedure could be a promising direction for preparing spin valve devices.

MA 3.2 Mon 9:45 H32

The influence of a temperature dependent anisotropy on the attempt frequency of single superparamagnetic nanodots — •Stefan Freercks[1], Alexander Neumann[1,2], Carsten Thönnissen[1], André Kobs[1,3], Eva-Sophie Wilhelm[1], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Germany — [2]Institut für Medizintechnik, Universität zu Lübeck, Germany — [3]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany

We have developed a feasible method to study the magnetization behavior of single nanodots with an anisotropy perpendicular to the film plane utilizing the anomalous Hall effect [1]. The telegraph noise of Pt/Co/Pt dots (diameter $<$ 40nm, Co thickness $<$ 1nm) is measured in the superparamagnetic regime. The switching frequency is determined and analyzed with the Néel-Arrhenius law. We obtain attempt frequencies that deviate by orders of magnitude from the commonly assumed GHz range [2]. To investigate the influence of the energy barrier, the anisotropy has been measured for the initial film and dots as a function of temperature. A small variation of the uniaxial anisotropy constant K_{Eff} is found, which explains the deviations in the attempt frequencies. 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 3.3 Mon 10:00 H32

Efficient high frequency rectification using CIP-GMR nanowires — •Philip Trempler[1] and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, MLU Halle-Wittenberg, Germany

We have recently shown [1] that by the help of in-plane spin-valve-nanowires alternating currents can be rectified. The nanowires consist of layer stack designed for current-in-plane (CIP) giant magnetoresistance (GMR). In the wires we use a 90° alignment of exchange bias of the fixed electrode and shape anisotropy of the free magnetic layer. In such a structure the Oersted field created by an AC current leads to a modulation of the conductivity that ultimately results in the creation of a DC voltage and thus rectification. We present experiments to maximize the efficiency of the rectification process and to combine several identical wires to obtain maximum DC voltage while maintaining a 50 Ω impedance suitable for high frequencies. [1] J. Kleinlein, B. Ocker, G. Schmidt, Appl. Phys. Lett. 104, 153507 (2014)

MA 3.4 Mon 10:15 H32

Fabrication and characterization of on-chip terminated micromachined giant magnetoimpedance (GMI) devices for strain and magnetic field sensing in the GHz regime — •Gregor Büttel and Uwe Hartmann — Institute of Experimental Physics, Saarland University, D66041, Saarbrücken, Germany

We have developed a combined fabrication process relying on lithography and silicon micromachining methods to obtain a coplanar waveguide based GMI device located over the bending edge between a Si3N4 cantilever and its support. 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. The signal line integrating a strain or magnetic-field-sensitive layer system can be scaled down to a width of a few microns. Magneto-optical Kerr microscopy, magnetic force microscopy and micromagnetic simulations are employed to investigate the domain structure and hysteresis curve of the device. We discuss appropriate material layer systems and micromagnetic simulations based on the MUMAX framework to control and study the magnetic domains and ferromagnetic resonance properties to gain more insight into the determining factors for a high GMI magnitude under applied stress/field.

15 min. break

MA 3.5 Mon 10:45 H32

High Amplitude Ferromagnetic Resonance in Sub-Micron Disks — •Markus Haertinger[1], Hans G. Bauer[1], Martin Decker[1], Chen Luo[1,2], Torsten Kachel[2], Georg Woltersdorf[1,3], and Christian H. Back[1] — [1]Department of Physics, Universität Regensburg, 93040 Regensburg, Germany — [2]Helmholtz-Zentrum Berlin, 12489 Berlin, Germany — [3]Department of Physics, Martin-Luther-Universität Halle, 06099 Halle(Saale), Germany

We investigate the modified linear and nonlinear response of the magnetization in confined magnetic elements. For this purpose we structured some Py disks on top of a coplanar waveguide. The size of the disks was varied between 300 and 800 nm for the diameter and between 20 and 40 nm for the thickness of the disks. In our experiments we use time resolved X-ray magnetic circular dichroism (XMCD) experiments to determine the excursion angle during the ferromagnetic resonance (FMR) experiments[1]. Additionally we can compare our experimental date with the results of micromagnetic simulations.

Our experiments provide us with the excitation dependence of the excursion angle of the precessing magnetization. For some of the larger disks we are able to resolve the transition from linear to the nonlinear regime. We found a reduction of the excursion angle for similar excitation field and decreased element dimensions.

[1] H.G. Bauer et al. Nature Commun. **6**, 8274 (2015)

MA 3.6 Mon 11:00 H32

Enhanced Magneto-Optical Edge Excitation in Nanoscale Magnetic Disks — •Andreas Berger[1], Rodrigo Alcaraz de la Osa[2], Anna Suszka[1], Matteo Pancaldi[1], Jose Maria Saiz[2], Fernando Moreno[2], Hans Peter Oepen[3], and Paolo Vavassori[1,4] — [1]CIC nanoGUNE — [2]Universidad de Cantabria — [3]Universität Hamburg — [4]Ikerbasque

We report an unexpected enhancement of the magneto-optical effect for permalloy disks with a diameter D of less than 400 nm [1]. The effect becomes increasingly pronounced for smaller D, reaching more than a 100% enhancement for D = 100 nm samples. By means of simulations we are able to reproduce the experimental behavior, including its dependence on D, disk thickness t, wavelengths λ and diffraction order m. The simulations furthermore identify the origin of this effect as a ring-shaped region at the disk edges, where the magneto-optically induced electric polarization is enhanced [1]. This leads to an enhancement of the magneto-optical effect, independent from any optical resonance. The edge-induced enhancement effect is substantial, even if the absolute size of the magneto-optical effect in our samples remains modest. However, far larger absolute values should be achievable by utilizing materials with substantially larger magneto-optical coupling strengths Q and even smaller nano-scale dimensions or sub-structures.

[1] A. Berger et al., Phys. Rev. Lett. 115, 187403 (2015)

MA 3.7 Mon 11:15 H32

Direct Imaging of Spin Wave Propagation in Antidot Lattice based Magnonic Crystals — •Joachim Gräfe[1], Ajay Gangwar[2], Ambra Caprile[3], Matthias Noske[1], Hermann Stoll[1], Christan H. Back[2], Gisela Schütz[1], and Eberhard J. Goering[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [2]Department of Physics, University of Regensburg, Regensburg, Germany — [3]Istituto Nazionale di Ricerca Metrologica, Turin, Italy

Magnonic crystals are nanostructured metamaterials with periodically alternating magnetic properties, similar to photonic crystals, which have gained significant scientific interest and can be realised by a regular lattice of holes, a so-called antidot lattice (ADL), in a magnetic thin film. As the spin wave propagation in nanoscaled ADL cannot be visualized by time resolved Kerr microscopy, typical investigations use all electrical spin wave spectroscopy or Brillouin light scattering and are unable to directly image the propagation of spin waves in nanometer sized magnonic crystals. Here, we present results from advanced time resolved x-ray microscopy (MAXYMUS@BESSY) of spin wave propagation and the mechanisms behind selective transmission or damping in these magnonic crystals. Therefore, magnon modes spanning from 250 MHz up to 8 GHz were resonantly excited and the influence of a variable applied field was investigated. These measurements allowed the direct observation of the individual modes, their interaction with the ADL, and their respective localisation within the lattice.

MA 3.8 Mon 11:30 H32

Toroidal ordering in a compensated nanomagnetic lattice — •Jannis Lehmann[1], Claire Donnelly[1,2], Sebastian Gliga[1,2], Peter Derlet[2], Dennis Meier[1], Laura Heyderman[1,2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Paul-Scherrer-Institute, Villigen PSI, Switzerland

Two-dimensional magnetic nanostructures show interesting ordering effects due to dipolar stray-field coupling of single macro-spins that yield, e.g., frustrated spin-ice behaviour. To obtain a net toroidal moment, the spins in a unit cell have to form a magnetic whirl. Here we present a nanomagnetic lattice that exhibits toroidal domains, which currently attract great attention due to their intrinsic space- and time-antisymmetric properties. Our structural unit cell consists of four lithographically written sub-micron permalloy islands that are arranged on a silicon substrate forming the edges of a square. We discuss the as-grown magnetic order and the influence of different island separations on the resulting toroidal domain structure. Using magnetic force microscopy, we show that domains of opposite chirality emerge that are separated by well-defined domain-wall states. Our results demonstrate the possibility of engineering the as-grown magnetic state. By tayloring the relative distances between the nanomagnets, we can control the toroidal domain size and the domain-wall geometry. This enables us to investigate the quantum-mechanically defined toroidal moment at a mesoscopic length scale, i.e., on a technically accessable classical level.

MA 3.9 Mon 11:45 H32

Electrical and thermal transport properties of FeCo thin films on SiN membrane based microcalorimeter — •Sasmita Srichandan, Matthias Kronseder, Christian Back, and Christoph Strunk — Institut für experimentelle und angewandte Physik, Universität Regensburg, Universitätstr. 31, 93053 Regensburg

We present the measurements of electrical resistivity, thermopower and thermal conductivity of 80nm thick films of Fe_xCo_{1-x} with compositions x = 0.3, 0.5, 0.64, 0.78 and 0.8 in a wide temperature range of 25 - 300 K. Our sample design consists of a rectangular SiN membrane structure suspended between two SiN islands covered with a ferromagnetic alloy film. Patterned thin wires of AuPd and Al constitute heaters and thermometers and assist in generating and measuring temperture difference between the two ends of the bridge respectively. Thermopower and thermal conductivity are measured at steady state while applying DC current to the heaters. All the measured transport coefficients exhibit strong dependence on temperature and the compositions of the alloys. At a given bath temperature the electrical resistivity increases monotonically with composition unlike typical binary alloys which show a maximum at x = 0.5 [1]. Deviation from Wiedemann Franz law is also observed. The measured transport coefficients are analysed to separate the contributions of different subsystems such as the electrons, phonons and magnons.

[1] C. Y. Ho et.al,*J. Phys. Chem. Ref. Data* **12** 183 (1983).

MA 4: Bio- und molekularer Magnetismus

Time: Monday 9:30–12:00 Location: H33

MA 4.1 Mon 9:30 H33

X-ray magnetic circular dichroism on self-assembled Fe_4 SMMs at surfaces — •Luca Gragnaniello[1], Philipp Erler[1], Stefano Rusponi[2], Peter Schmitt[3], Andreas Irmler[1], Fabian Paschke[1], Sabina Simon[1], Nicole Barth[1], Thomas Huhn[3], Harald Brune[2], Fabian Pauly[1], and Mikhail Fonin[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Institute of Condensed Matter Physics (ICMP), École Polytechnique Fédérale de Lausanne (EPFL), Station 3, CH-1015 Lausanne, Switzerland — [3]Fachbereich Chemie, Universität Konstanz, 78457 Konstanz, Germany

By using electrospray ion beam as a soft deposition method in ultra-high vacuum, we were able to organize Fe_4 SMMs in a highly regular superstructure on hexagonal boron nitride/Rh(111) [1] and graphene/Ir(111) templates, as evidenced by scanning tunneling microscopy measurements. On both these substrates Fe_4 SMMs lay on the surface with a well-defined flat geometry, corresponding to a homogeneous out-of-plane orientation of the magnetization easy axis of the molecules. Through x-ray magnetic circular dichroism measurements on those systems, we revealed that the magnetic anisotropy of SMMs can be deeply influenced by the choice of the substrate.

[1] P. Erler et al., Nano Lett. 15, 4546-4552 (2015)

MA 4.2 Mon 9:45 H33

Long-range 2D-ferrimagnetic ordering in a chessboard-like supramolecular Kondo lattice — •Milos Baljozovic[1], Jan Girovsky[1], Jan Nowakowski[1], Md. Ehesan Ali[2], Harald R. Rossmann[1], Thomas Nijs[3], Elise Aeby[3], Sylwia Nowakowska[3], Dorota Siewert[3], Gitika Srivastava[1], Christian Wäckerlin[4], Jan Dreiser[1], Silvio Decurtins[5], Shi-Xia Liu[5], Peter M. Oppeneer[2], Thomas A. Jung[1], and Nirmalya Ballav[6] — [1]PSI, Switzerland — [2]Uppsala University, Sweden — [3]Universität Basel, Switzerland — [4]EPFL, Switzerland — [5]Universität Bern, Switzerland — [6]IISER, India

Recently, there has been raising interest in investigations of fundamental magnetic interactions in low-dimensional systems. One such interaction is the Kondo effect responsible for suppression of the local moment, while another one, the RKKY coupling gives rise to a long-range spin ordering. Spin-bearing molecules on metallic substrates present a platform to study the interplay of these two opposing effects and can lead to even more intriguing phenomena. Here we present the first direct observation of long-range ferrimagnetic order in a 2D molecular Kondo lattice created by the co-assembly of FeFPc and MnPc molecules. The chessboard-like patterns on Au(111) substrates, have been investigated by STM/STS, XMCD and the DFT+U. At the first glance 2D and 1D ordering is in conflict with the classical theory of magnetism. In the present system, however, the substrate is of key importance; observed AFM coupling between the Mn and Fe centers is mediated by the surface states of Au(111) making the ordering possible.

MA 4.3 Mon 10:00 H33

The Optical and Thermal Spin State Manipulation of $Fe(bpz)_2bipy$ and its Derivative Compounds on Graphite Surface — •Lalminthang Kipgen[1], Holger Naggert[2], Matthias Bernien[1], Fabian Nickel[1], Lucas M. Arruda[1], Andrew J. Britton[1], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Germany — [2]Institut für Anorganische Chemie, Christian-Albrechts Universität zu Kiel, Germany

The control of the spin state of molecules from the high-spin (HS) to the low-spin state (LS) or *vice versa* by thermal and optical means is envisioned to provide the ultimate building blocks for future spintronic devices. To this end, the understanding of the nature of the interaction of molecules and surfaces is crucial. Various molecule-substrate systems have been studied, and for sub-monolayer coverages, the transition is often quenched or co-existence of HS and LS at all temperature has been reported. Here, we report the thermal and optical manipulation of the spin states of submonolayers of $Fe(bpz)_2bipy$, $Fe(bpz)_2bipy\text{-}me_2$ and $Fe(bpz)_2bipy$-tert(butyl) on highly oriented pyrolytic graphite surface, using x-ray absorption spectroscopy. All the molecules are found to be HS stabilized at 300 K, but they exhibit contrasting spin state behavior at low temperatures. Only $Fe(bpz)_2bipy$ undergoes complete thermal spin state switching at low temperatures. It exhibits complete spin state conversion from LS to HS at 5 K by illumination with green light, and can be converted back to LS by increasing the temperature to 60 K. This work is supported by DPG through sfb 658 and sfb 677.

MA 4.4 Mon 10:15 H33

Manipulation of the magnetic coupling in deposited molecular macrocycles — •Heike Herper and Barbara Brena — Department of Physics and Astronomy, Uppsala University, Sweden

We present a first principles study focussing on the manipulation of the magnetic coupling of Fe phthalocyanine (FePc) deposited on metallic substrates. FePc couples FM to a Co(001) substrate. The coupling can be reversed by an O adlayer but the calculated coupling energies are large. [1] To overcome this problem higher coverages have been used. As in a spin valve the magnetization of the lower molecule is fixed by the FM film and the coupling between the molecules can vary. For $(FePc)_2$ on Co(001) the coupling is 5 times smaller than for FePc/O/Co(001). To reverse the sign of the coupling different axial ligands have been used. A Cl ligand attached to $(FePc)_2$ reverses the sign of the intermolecular coupling. Depending on the ligand also the spin state of the ligand may change [2].

To eliminate the molecule-substrate coupling FePc has been deposited on nonmagnetic Cu(001). The exchange coupling in $(FePc)_2$ on Cu(001) turns out to be weaker as in the free $(FePc)_2$ and is accompanied by a significant charge transfer.

All calculations have been performed using the VASP code and a Hubbard U on Fe. The U for the free molecule has been calculated within linear response as implemented in QUANTUM ESPRESSO.

[1] D. Klar *et al.*, Phys Rev B **88**, 224424 (2013)

[2] B. Brena and H. C. Herper, J. Appl. Phys. **117**, 17B318 (2015)

15 min. break

MA 4.5 Mon 10:45 H33

X-ray absorption study of thermally-induced electrocyclic ring closure of iron porphyrin molecules on Au(111) — •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 a particular porphyrin molecule, iron octaethylporphyrin and its transition to iron tetrabenzoporphyrin through a surface-assisted intramolecular ligand reaction mediated by thermal stimulation on a Au(111) single crystal substrate [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 iron magnetic moment is substantially increased, a result corroborated by the calculated DOS, which suggests a change in the spin state from 1 to 3/2. — 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 4.6 Mon 11:00 H33

Ferromagnetic Multi-Magnon Excitations in the High-Spin Molecule Mn_{19} — •Siyavash Nekuruh[1], K. Prsa[1], J. Nehrkorn[1], B. Burger[2], A.M. Ako[2], C.E. Anson[2], Y. Lan[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)

The ferromagnetically coupled molecule Mn_{19} with its world record high-spin ground state S = 83/2 has attracted considerable interest in the past. From the chemistry point of view determining the exchange coupling constants and their comparison to e.g. DFT calculations is of interest, while in physics understanding the spin-wave excitations in such a molecule is in the focus.

We here present a detailed study of the magnetic excitations in Mn_{19} by inelastic neutron scattering (INS). The INS spectra in the simpler model systems Mn_{10} and $Mn_{18}Sr$ were previously successfully interpreted in terms of ferromagnetic cluster spin waves. However, in Mn_{19} an additional excitation at low energies is present, which was not observed in Mn_{10} and $Mn_{18}Sr$. It shows an unusual behaviour for exchange-only clusters, but is reminiscent of a collective excitation. We find that Mn_{19} cannot be treated in a non-interacting spin-wave picture; an inherent many-body description is required. Mn_{19} is thus a unique example of a magnetic molecule showing both cluster-type and collective-type magnetic excitations.

MA 4.7 Mon 11:15 H33

Investigation of Ni_2-complexes with Different Radical Bridges by High-Frequency Electron Spin Resonance — •Msia Tavhelidse[1], Cebrail Pür[1], Roland Bischoff[2], Manuel Reh[2], Hans-Jörg Krüger[2], Changhyun Koo[1], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics, Heidelberg University, Heidelberg, Germany. — [2]Department of Chemistry, University of Kaiserslautern, Kaiserslautern, Germany.

Magnetic properties of two Ni_2 complexes, i.e. [{Ni(L-N_4Me_2)}$_2$ (bpym^{*-}}] $(ClO_4)_3$ (I) and [{Ni(L-N_4Me_2)}$_2$ (μ-bptz)] $(ClO_4)_3$ (II), with different radical bridges are investigated by means of high-frequency electron spin resonance (HF-ESR) studies. In both complexes, Ni^{2+} ions (S = 1) are ferromagnetically coupled through a radical bridge with an unpaired electron. The high-spin S = 5/2 ground state is confirmed by the HF-ESR spectra which exhibit five almost equally separated resonance features. The frequency dependence of the resonances enables reading off significant zero-field-splitting (ZFS) for complexes. Temperature and frequency dependence of the spectra is analysed by means of exact diagonalization of the corresponding spin Hamiltonians. Best simulations of the experimental data unambiguously yields g-factors and anisotropy parameters of both complexes: g_z=2.12, D=-1.15 K, and B_4^0=-1.44·10^{-4} K for complex I, and g_z=2.07, D=-1.58 K, and B_4^0=-2.88·10^{-4} K for complex II. Spectral weight shift as a function of the temperature supports the best simulation parameters.

MA 4.8 Mon 11:30 H33

XAS and XMCD of Dy Complexes on Au(111) — •Matthias Bernien[1], Paul Stoll[1], Daniela Rolf[1], Fabian Nickel[1], Qingyu Xu[1,2], Claudia Hartmann[1], Tobias R. Umbach[1], Jens Kopprasch[1], Janina N. Ladenthin[1], Enrico Schierle[3], Eugen Weschke[3], Constantin Czekelius[4], Katharina J. Franke[1], and Wolfgang Kuch[1] — [1]Freie Universität Berlin, Institut für Experimentalphysik, 14195 Berlin, Germany — [2]Department of Physics, Southeast University, 211189 Nanjing, P. R. China — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [4]Heinrich-Heine Universität Düsseldorf, Institut für Organische und Makromolekulare Chemie II, 40225 Düsseldorf, Germany

Lanthanide complexes are promising candidates for spintronic applications due to their unique magnetic properties like e.g. strong magnetic anisotropy, high magnetic moment, and slow relaxation of magnetization. By means of X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) at $T = 4.5$ K and $B = 6$ T we find that Dy-tris(1,1,1-trifluoro-4-(2-thienyl)-2,4-butanedionate) molecules on Au(111) display an easy-axis anisotropy parallel to the surface. Upon adsorption, the coordination of the Dy^{3+} ion by its three ligands is deformed due to the interaction with the surface, stabilizing an unusual $M_J = 15/2$ ground state (GS). Due to its cylindrical charge density distribution such a GS is disfavored in the free complex as well as in Dy-bis(phthalocyaninato) complexes where $M_J = 13/2$ GSs are observed. — This work is supported by the DFG through Sfb 658.

MA 4.9 Mon 11:45 H33

Origin of the high blocking temperature in the $Tb_2N_2^{3-}$ single molecule magnet — •Krunoslav Prsa[1], J. Nehrkorn[1], S. Nekuruh[1], J. Corbey[2], J.D. Rinehart[3], T. Guidi[4], J.R. Long[3], W.J. Evans[2], and Oliver Waldmann[1] — [1]Physikalisches Institut Universität Freiburg, Germany — [2]Department of Chemistry, University of California, Irvine, USA — [3]Department of Chemistry, University of California, Berkeley, USA — [4]ISIS Facility, STFC Rutherford Appleton Laboratory, UK

The single molecule magnets containing magnetic rare-earth ions may lead to practical applications. The main challenge — weak interaction between the $4f$–electrons — was recently overcome in an N_2^{3-} radical–bridged dinuclear lanthanide molecular complex, resulting in a world record high blocking temperature of 14.3 K in $Tb_2N_2^{3-}$. We recorded the inelastic neutron scattering (INS) data on this molecule, its parent compound $Tb_2N_2^{2-}$ and non-magnetic analogue $Y_2N_2^{3-}$. In addition to ligand field levels, we observed excitations due to the exchange coupling. We present our fits to the INS spectra and thermodynamical data. Compared to the parent compound, the N_2^{3-} radical bridge brings two changes: (1) Its additional electronic charge influences the Tb^{3+} single ion ground state. (2) Its additional electron serves as an $S = 1/2$ magnetic bridge between the terbium magnetic moments and hence enhances their effective magnetic interaction. Our simplified model compromises between a reduced number of parameters and the preservation of the structural information to carefully disentangle the two aforementioned effects.

MA 5: Spin Textures and magnetic Phase Transitions

Time: Monday 9:30–13:30 Location: H34

Invited Talk MA 5.1 Mon 9:30 H34

Néel-type skyrmions in a type-I multiferroic compound — •Istvan Kezsmarki[1], Sandor Bordacs[1], Peter Milde[2], Jonathan White[3], Vladimir Tsurkan[4], and Alois Loidl[4] — [1]Department of Physics, Budapest University of Technology and Economics, Budapest, Hungary — [2]Institut für Angewandte Photophysik, TU Dresden, Dresden, Germany — [3]Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institut, Villigen, Switzerland — [4]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

GaV4S8, a member of the lacunar spinel family, is the first known example of skyrmion-host materials with non-chiral but polar crystal structure. This compound is a magnetic semiconductor with a rhombohedral crystal symmetry (R3m) and an easy-axis magnetic anisotropy. In this compound we observed the formation of a Néel-type skyrmion lattice, which exists over a broad temperature range [1]. This is in contrast to Bloch-type skyrmions found in chiral magnets, which are stabilized by thermal fluctuations in small pockets of the phase diagram. We found that the orientation of these Néel-type skyrmions is not controlled by the external magnetic field, but instead confined to the magnetic easy axis. Due to the polar nature of the host crystal, these magnetic skyrmions wear a ferroelectric dressing and exhibit strong static and dynamic magnetoelectric effects [2,3].

[1] I. Kézsmárki et al., Nat. Mater. 14, 1116 (2015) [2] E. Ruff et al., Sci. Advances 1, e1500916 (2015) [3] Z. Wang et al., Phys. Rev. Lett. 115, 207601 (2015)

15 min. break

MA 5.2 Mon 10:15 H34

Four-ion magnetic coupling in the heavy rare earth elements — •Eduardo Mendive Tapia and Julie Staunton — Department of Physics, University of Warwick, Coventry CV4 7AL, U.K.

The study of the magnetic properties of the heavy rare earth elements has attracted much attention owing to the complexity of their magnetic order. A complex series of magnetic phases, spanning antiferromagnetic (AF) helical, conical helical and fan phases and also ferromagnetic states is formed as the temperature and applied magnetic field are varied. The AF phases are usually incommensurate with the underlying hexagonal close packed lattice. The origin of these magnetic structures derives from the indirect interaction of the local moments, formed from localized 4f states, which is mediated by the conduction electrons. Here we employ an ab-initio Disordered Local Moment (DLM) theory to investigate the magnetic phase transitions. The orientations of thermally fluctuating 'local moments' associated with the 4f electrons are considered to vary slowly on the scale of the faster itinerant conduction electronic motions which in turn drive the indirect interactions between the local moments. We focus on the study of transitions that are characteristic of the common valence electronic structure among the heavy rare earth elements. As a main result, we identify an isotropic four-ion magnetic coupling, emerging from the nature of the conduction electronic structure, as the decisive driving factor for the temperature and field evolution of the magnetic ordering.

MA 5.3 Mon 10:30 H34

Skyrmionic phases and skyrmion lifetime in an ultrathin magnetic film — Levente Rózsa[1,2], Eszter Simon[1], Krisztián Palotás[1], László Udvardi[1], 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

In ultrathin magnetic films, the Dzyaloshinsky-Moriya interaction (DMI) between local magnetic moments can lead to the formation of chiral spin structures like spin-spirals and magnetic skyrmions. Particularly interesting are magnetic phase transitions influenced by DMI. In this work we determined the magnetic B-T phase diagram of PdFe bilayer on Ir(111) surface by performing Monte Carlo and spin dynamics simulations based on an effective classical spin model. The parameters of the spin model were determined by ab initio methods. At low temperatures we found three types of ordered phases, while at higher temperatures, below the completely disordered paramagnetic phase, a large region of the phase diagram is associated with a fluctuation-disordered phase. Within the applied model, this state is characterized by the presence of skyrmions with finite lifetime. According to the simulations, this lifetime follows the Arrhenius law as a function of temperature [1].

[1] L. Rózsa, E. Simon, K. Palotás, L. Udvardi, L. Szunyogh arXiv:1510.04812 (2015)

MA 5.4 Mon 10:45 H34

Optically probing symmetry breaking in the Skyrmion cuprate Cu_2OSeO_3 — •Rolf B. Versteeg[1], Ignacio Vergara[1], Simon Schäfer[1], Dario Bischoff[1], Aisha Aqeel[2], Thomas T.M. Palstra[2], Markus Grüninger[1], and Paul H.M. van Loosdrecht[1] — [1]II. Physikalisches Institut - Universität zu Köln, Zülpicher Straße 77, 50937 Cologne, Germany — [2]Zernike Institute, Nijenborgh 4, 9747AG Groningen, The Netherlands

Cubic chiral crystal structures provide an ideal platform for the creation and manipulation of topologically protected spin-vortex structures known as Skyrmions. In these materials, the absence of inversion symmetry, the chiral crystal structure, different types of magnetic order, and their coupling to one another give rise to a multitude of linear optical phenomena. These can be used in all-optical methods to access the various magnetic phases as well as the Skyrmion dynamics.

Here, we present a study of the optical properties of the Skyrmion cuprate Cu_2OSeO_3. Through ellipsometry, we show the existence of dipole-active local crystal-field excitations. Spectroscopic polarimetry is further used to study the different sources of optical rotation present in Cu_2OSeO_3. The natural optical rotation, originating in the chiral crystal structure, shows the presence of a zero-field magnetoelectric coupling. The magneto-optical activity, quantified by a Verdet coefficient as large as $V=-35\cdot10^3$ rad/T·m, allows us to map the magnetic phase diagram, including the Skyrmion lattice phase. Our results show that optical detection of the Skyrmion phase in Cu_2OSeO_3 is possible and opens new paths in probing of magnetic topological matter.

MA 5.5 Mon 11:00 H34

Influence of lattice strain on the formation of magnetic skyrmions — •Julian Hagemeister, Elena Vedmedenko, and Roland Wiesendanger — University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

The properties of magnetic skyrmions have both experimentally and theoretically mainly been investigated in the context of materials providing an isotropic environment up to now. There are only few publications that deal with the influence of anisotropic environments among which is the recent report about the observation of deformed skyrmions in chiral magnets with crystal strain [1]. However, the strain is often inevitable even in epitaxially grown magnetic films. Here, the influence of spatially varying strain on the magnetic structure of spin spirals and skyrmions is studied. It is shown that a distortion of the atomic structure leading to changes in the exchange tensor results in periodic deformation of non-collinear magnetic structures. Particularly, we find that the wave vector of magnetic spirals is directly related to the periodicity of the spatial variation of the exchange interaction. This effect can induce a zigzag shape of the wave fronts as well as anisotropic skyrmion lattices, when an external magnetic field is applied. The results can be used to engineer skyrmion tracks similar to the ones proposed recently [2].

[1] K. Shibata, et al. Large anisotropic deformation of skyrmions in strained crystal Nat. Nanotechnol. 10, 589-592 (2015).

[2] Fert, A., Cros, V. & Sampaio, J. Skyrmions on the track. Nat. Nanotechnol. 8, 152-156 (2013).

MA 5.6 Mon 11:15 H34

Ultrafast cooling and heating mechanisms of the laser induced phase transition in CuO — •Johan Hellsvik[1], Johan H. Mentink[2], and José Lorenzana[3] — [1]KTH, Stockholm, Sweden — [2]Radboud University Nijmegen, The Netherlands — [3]ISC-CNR, Rome, Italy

We report theoretical modeling of the sub-picosecond magnetic phase transition [1] which recently has been experimentally observed in optically pumped samples of multiferroic CuO [2]. Using atomistic spin dynamics simulations we observe that independently of the excitation mechanism, the phase transition from collinear to spin-spiral order can proceed in exchange interaction driven dynamics on picosecond time scales. Intriguingly, different excitation mechanisms are found to drive distinct dynamics, in which the spin system either cools down or heats up on sub picosecond time scales [3].

[1] Johnson et al., Phys. Rev. Lett. 108, 037203 (2012) [2] Kimura et al., Nat. Mater. 7, 291 (2008) [3] Hellsvik et al., arXiv:1509.03202

MA 5.7 Mon 11:30 H34

Tunable magnetic phase transitions in ultrathin films — Levente Rózsa[1,2], László Udvardi[1], •László Szunyogh[1], and István A. Szabó[3] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary — [3]University of Debrecen, Debrecen, Hungary

The Dzyaloshinsky-Moriya interaction (DMI) between local magnetic moments has a great impact in spintronics applications. In this contribution we present theoretical investigations of the magnetic properties of an Fe monolayer on W and Ta (110) surfaces. We found different types of ground states as a function of the inward relaxation of the Fe layer varied between 10% and 17% with respect to the ideal layer spacing of the substrate. In case of W(110) substrate this is reflected in a reorientation of the easy axis from in-plane to out-of-plane. For Ta(110) a switching appears from the ferromagnetic state to a cycloidal spin spiral state, then to another spin spiral state with larger wave vector and, for even larger relaxations, a rotation of the normal vector of the spin spiral is found. Classical Monte Carlo simulations indicate temperature-induced transitions between the different magnetic phases observed in the Fe/Ta(110) system. Moreover, we use finite-temperature spin wave theory to explain and analyze these phase transitions qualitatively and quantitatively [1].

[1] L. Rózsa, L. Udvardi, L. Szunyogh, I. A. Szabó, Phys. Rev. B 91, 144424 (2015)

15 min break

MA 5.8 Mon 12:00 H34

Emergent Phases in quantum magnets — •Markos Skoulatos[1], Christian Pfleiderer[1], and Astrid Schneidewind[2] — [1]Physik-Department, Technische Universitaet Muenchen, D-85748 Garching, Germany — [2]Juelich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Juelich GmbH, Garching, Germany

Quantum magnets exhibit exotic ground states and novel elementary excitations, complex correlations and generic quantum critical points. Phenomena like frustration, condensation and quantum disorder are at the very heart of this field. More interestingly, novel emergent behavior can arise as a result of interplay between different characters of the same system. Examples include spin and orbital interplay in Mott insulators or spin liquid and spin nematic phases arising due to frustration in very simple model systems. In the light of this, some new results will be briefly discussed.

MA 5.9 Mon 12:15 H34

Magnetic order via long ranged RKKY interaction in frustrated pyrochlore magnets — •Sebastian Paeckel[1] and Paul McClarty[2] — [1]Georg-August Universität - Institut für Theoretische Physik, Göttingen — [2]Wandham college, University of Oxford

Recent experiments on Pr2Ir2O7, which is poised close to a metal-insulator transition, revealed confusing low-temperature behaviour e.g. a large anomalous hall effect accompanied with an unmeasurable small magnetization at T < 1K with no sign of long ranged magnetic order which led some authors to suggest Pr2Ir2O7 as a candidate for a metallic spin liquid[1,2]. Remarkably Pr2Ir2O7 is the only compound in the pyrochlore iridate series which exhibits metallic behaviour naturally leading to the question on how the itinerant character of the 5d Ir system influences the ordering behaviour of the geometrically frustrated localised Pr moments.

In my talk I'm going to present results of calculations of the magnetic phase diagram for a simplified model capturing the interplay between classical localised magnetic moments and itinerant S=1/2 fermions with both constituents placed on a pyrochlore lattice. Taking into consideration the full long ranged character of the induced RKKY interaction then permits to relate the emerging magnetic structures to the frustrated nature of the itinerant electronic system.

[1] S. Nakatsuji, Y. Machida, J. J. Ishikawa, S. Onoda & Y. Karaki, Journal of Physics: Conference Series 320 (2011) 012056

[2] S. Nakatsuji, Y. Machida, Y. Maeno, T. Tayama et al., PRL 96, 087204 (2006)

MA 5.10 Mon 12:30 H34

Zero-field μSR and HF-EPR study on complex magnetic order in layered trigonal $MnSb_2O_6$ — •Changhyun Koo[1], Rajib Sarkar[2], Michael Tzschoppe[1], Johannes Werner[1], Elena A. Zvereva[3], Hans-Henning Klauss[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics, Heidelberg University, Germany — [2]Institute for Solid State Physics, TU Dresden, Germany — [3]Faculty of Physics, Moscow State University, Russia

A new phase of $MnSb_2O_6$ (P-31m) is studied by static and dynamic magnetic probes. SQUID data imply AFM order below $T_N = 8.5$ K and a spin-flop transition at $B_{SF} \leq 1$ T. Antiferromagnetic resonance (AFMR) modes observed by means of high-frquency ESR confirm the AFM ground state and suggest a zero field splitting of 16.5 GHz. For $B < B_{SF}$, static magnetization data exhibit an anomaly at around 5.5 K which may be associated with the evolution of an incommensurate AFM phase predicted by theory [1]. Zero-field μSR measurements do not confirm the presence of weak ferromagnetism below 41 K [1]. At high temperatures, the μSR spectra follow a general exponential behavior which corresponds to fluctuations of electronic moments. Below T_N, μSR spectra show damped oscillation because of well-defined static internal fields at the muon site implying long range magnetic ordering. The magnetic order parameter is extracted and a clear λ-like anomaly in the relaxation rate is observed at T_N.

[1] V. B. Nalbandyan et al. Inorg. Chem. 54, 1705 (2015)

MA 5.11 Mon 12:45 H34

Critical phenomena in uniformly frustrated systems — •Bhilahari Jeevanesan[1], Karim Mnasri[2], and Jörg Schmalian[1,3] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute for Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

The field theory and statistical mechanics of uniformly frustrated systems is frequently studied by placing systems in curved background geometries. We study the critical behavior of an N-component ϕ^4-theory in hyperbolic space, which has the role of uniformly frustrating the magnetic order described by ϕ. We treat this model in a 1/N expansion and find that it exhibits a second-order phase transition with an unusual magnetization texture that results from the lack of global parallelism in hyperbolic space. Angular defects occur on length scales comparable to the radius of curvature. This phase transition is governed by a new strong curvature fixed point that obeys scaling below the upper critical dimension $d_{uc} = 4$. The exponents of this fixed point are given by the leading order terms of the 1/N expansion.

MA 5.12 Mon 13:00 H34

Neutron Depolarisation Imaging of the Ferromagnetic Kondo Lattice System $CePd_{1-x}Rh_x$ — •Marc Seifert[1,2], Philipp Schmakat[1,2], Michael Schulz[2], Christoph Geibel[3], Micha Deppe[3], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik-Department, D-84578 Garching, Germany — [2]Forschungs-Neutronenquelle FRM-II, D-84578 Garching, Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany

The ferromagnetic Kondo lattice system $CePd_{1-x}Rh_x$ crystallises in the orthorhombic CrB crystal structure with a magnetic easy axis along the *c*-axis. We present a detailed neutron depolarisation study, where we oriented the *c*-axis of a $CePd_{1-x}Rh_x$ single crystal with $x = 0.40$ perpendicular to the polarisation of the neutron beam. Application of an external field of a few mT reveals an oscillation of the neutron polarisation signal close to the ferromagnetic ordering temperature at $T_c = 5.3$ K. We explain this oscillation with a Larmor precession of the polarisation vector around the stray field direction favoured due to anisotropy. Furthermore, we can extract the dc susceptibility, the angle between the magnetisation and polarisation, and the absolute value of the magnetisation from the oscillations. The values inferred are in good agreement with theoretical calculations.

MA 5.13 Mon 13:15 H34

Study of the Magnetic Excitations in the Dimer Compound Ba3-xSrxCr2O8 — •Alsu Gazizulina[1], Henrik Grundmann[1], Diana 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

Spin dimer systems, such as Ba3Cr2O8 and Sr3Cr2O8 show a field induced phase transition that can be described in terms of a Bose-Einstein condensation (BEC) of magnetic quasiparticles (triplons) in connection with the collective dimer states. The respective critical fields of Ba3Cr2O8 and Sr3Cr2O8 differ strongly due to a large difference in the strength of the intradimer magnetic interaction constant J0. For the corresponding solid solution Ba3-xSrxCr2O8, the strength of this interaction constant has been reported to be tunable in a non-linear way in a wide range by changing the Sr content x. Recently, we were able to grow single crystal samples of Ba0.1Sr2.9Cr2O8 and Ba0.2Sr2.8Cr2O8. . Our initial results for Ba0.1Sr2.9Cr2O8 point out to an intradimer exchange coupling J0 to be 5.18 meV, smaller than the value for the pure compound Sr3Cr2O8 of 5.55 meV.

MA 6: Transport: Quantum Coherence and Quantum Information Systems - Experiment (Joint session of HL, MA and TT organized by TT)

Time: Monday 9:45–13:00 Location: H22

MA 6.1 Mon 9:45 H22

Tunable coupling between fixed-frequency superconducting transmon qubits — •Stefan Filipp[1], David C. McKay[2], Easwar Magesan[2], Antonio Mezzacapo[2], Jerry M. Chow[2], and Jay M. Gambetta[2] — [1]IBM Research - Zurich, 8803 Rueschlikon, Switzerland — [2]IBM TJ Watson Research Center, Yorktown Heights, NY, USA

The controlled realization of qubit-qubit interactions is essential for both the physical implementation of quantum error-correction codes and for reliable quantum simulations. Ideally, the fidelity and speed of corresponding two-qubit gate operations is comparable to those of single qubit operations. In particular, in a scalable superconducting qubit architecture coherence must not be compromised by the presence of additional coupling elements mediating the interaction between qubits. Here we present a coupling method between fixed-frequency transmon qubits based on the frequency modulation of an auxiliary circuit coupling to the individual transmons. Since the coupler remains in its ground state at all times, its coherence does not significantly influence the fidelity of consequent entangling operations. Moreover, with the possibility to create interactions along different directions, our method is suited to engineer Hamiltonians with adjustable coupling terms. This property can be utilized for quantum simulations of spins or fermions in transmon arrays, in which pairwise couplings between adjacent qubits can be activated on demand.

MA 6.2 Mon 10:00 H22

Concentric transmon qubit featuring fast tunability and an anisotropic magnetic dipole moment — •Jochen Braumüller[1], Martin Sandberg[2], Michael R. Vissers[2], Andre Schneider[1], Steffen Schlör[1], Lukas Grünhaupt[1], Hannes Rotzinger[1], Michael Marthaler[1], Alexander Lukashenko[1], Amadeus Dieter[1], Alexey V. Ustinov[1,3], Martin Weides[1,4], and David P. Pappas[2] — [1]Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]National Institute of Standards and Technology, Boulder, Colorado 80305, USA — [3]National University of Science and Technology MISIS, Moscow 119049, Russia — [4]Johannes Gutenberg University, Mainz, 55128 Mainz, Germany

We present a planar qubit design based on a superconducting circuit that we call concentric transmon. While employing a straightforward fabrication process using Al evaporation and lift-off lithography, we observe qubit lifetimes and coherence times in the order of $10\,\mu$s. We systematically characterize loss channels such as incoherent dielectric loss, Purcell decay and radiative losses. The implementation of a gradiometric SQUID loop allows for a fast tuning of the qubit transition frequency and therefore for full tomographic control of the quantum circuit. Due to the large loop size, the presented qubit architecture features a strongly increased magnetic dipole moment as compared to conventional transmon designs. This renders the concentric transmon a promising candidate to establish a site-selective passive direct $\hat{Z}$ coupling between neighboring qubits, being a pending quest in the field of quantum simulation.

MA 6.3 Mon 10:15 H22

Quasiparticle-Induced Decoherence of Microscopic Two-Level-Systems in Superconducting Qubits — •Alexander Bilmes[1], Jürgen Lisenfeld[1], Sebastian Zanker[1], Michael Marthaler[2], Gerd Schön[2], Georg Weiss[1], and Alexey V. Ustinov[1] — [1]PHI, KIT, 76131 Karlsruhe, Germany — [2]TFP, KIT, 76131 Karlsruhe, Germany

Parasitic Two-Level-Systems (TLS) are one of the main sources of decoherence in superconducting nano-scale devices such as SQUIDs, resonators and quantum bits (qubits), although the TLS' microscopic nature remains unclear. We use a superconducting phase qubit to detect TLS contained within the tunnel barrier of the qubit's Al/AlOx/Al Josephson junction. If the TLS transition frequency lies within the $6-10\,$GHz range, we can coherently drive it by resonant microwave pulses and access its quantum state by utilizing the strong coupling to the qubit. Our previous measurements of TLS coherence in dependence of the temperature indicate that quasiparticles (QPs), which diffuse from the superconducting Al electrodes into the oxide layer, may give rise to TLS energy loss and dephasing [1]. Here, we probe the TLS-QP interaction using a reliable method of *in-situ* QP injection via an on-chip dc-SQUID that is pulse-biased beyond its switching current. The QP density is calibrated by measuring associated characteristic changes to the qubit's energy relaxation rate. We will present experimental data which show the QP-induced TLS decoherence in good agreement to theoretical predictions.

[1] J. Lisenfeld et al., PRL **105**, 230504 (2010)

MA 6.4 Mon 10:30 H22

Transmon qubits enter circuit nano-electromechanics — •Daniel Schwienbacher[1,2], Matthias Pernpeintner[1,2,3], Friedrich Wulschner[1,2], Philip Schmidt[1,2,3], Frank Deppe[1,2,3], Achim Marx[1], Rudolf Gross[1,2,3], and Hans Huebl[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

The field of cavity nano-electromechanics combines nano-scale mechanical elements with microwave circuits for the investigation of the light-matter interaction on a quantum level. In this context ground state cooling, electromechanically induced transparency effects, as wells as state transfer between the mechanical and photonic modes have been demonstrated. Recently, Abdi et al.[1] have proposed the integration of a nanomechanical beam into the capacitor of a transmon qubit, which is in turn coupled to a microwave resonator and predicted enhanced electro-mechanical coupling rates as well as the preparation of mechanical Fock states and the generation of three-partite entanglement. Here, we present an experimental study concerning the integration of a nanomechanical beam, a transmon qubit, and a microwave resonator on a single chip. We will discuss fabricational aspects and first spectroscopy data of the device.

We thankfully acknowledge financial support by the DFG via the collaborative research center SFB 631.

[1] Mehdi Abdi et al., PRL **114**, 173602 (2015)

MA 6.5 Mon 10:45 H22

Thermal microwave states acting on a superconducting qubit — •Jan Goetz[1,2], Miriam Müting[1,2], Max Haeberlein[1,2], Friedrich Wulschner[1,2], Edwar Xie[1,2,3], Peter Eder[1,2,3], Michael Fischer[1,2], Frank Deppe[1,2], Kirill Fedorov[1,2], Hans Hübl[1,2], Frank Deppe[1,2,3], 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), Schellingstraße 4, 80799 München, Germany

We analyze the influence of broadband thermal states in the microwave regime on the coherence properties of a superconducting (transmon) qubit coupled to a transmission line resonator. We generate the thermal states inside the resonator by heating a 30 dB attenuator to emit blackbody radiation into a transmission line. In the absence of thermal fluctuations, the qubit coherence time is limited by relaxation. We find that the relaxation rate is almost unaffected by the presence of a thermal field inside the resonator. However, such states induce significant dephasing which increases quadratically with the number of thermal photons, whereas for a coherent population of the resonator, the increase shows a linear behavior. These results confirm the different photon statistics, being Poissonian for a coherent population and super-Poissonian for a thermal population of the resonator.

This work is supported by the German Research Foundation through SFB 631 and FE 1564/1-1, EU projects CCQED, PROMISCE, the doctorate program ExQM of the Elite Network of Bavaria.

MA 6.6 Mon 11:00 H22

Displacement of squeezed propagating microwave states — •Kirill G. Fedorov[1], P. Yard[1,2], S. Pogorzalek[1,2], P. Eder[1,2,3], M. Fischer[1,2,3], J. Goetz[1,2], F. Wulschner[1,2], E. Xie[1,2,3], 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, Technische Universität München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), Schellingstraße 4, 80799 München, Germany

The displacement of propagating quantum states of light is a fundamental operation for quantum communication. It can be applied to fundamental studies of macroscopic quantum coherence and has an important role in quantum teleportation protocols with continuous variables. We study an experimental implementation of this operation for propagating squeezed microwave states. We generate these states using a Josephson parametric amplifier and implement the displacement operation using a specific cryogenic directional coupler. We demonstrate that even for strong displacement amplitudes we do not observe any degradation of the reconstructed quantum states. Furthermore, we confirm that path entanglement generated using displaced squeezed states, also stays constant over a wide range of the displacement power.

We acknowledge support by the German Research Foundation through SFB 631 and FE 1564/1-1, the EU project PROMISCE, and Elite Network of Bavaria through the program ExQM.

15 min. break

Invited Talk MA 6.7 Mon 11:30 H22

Coherent Suppression of Quasiparticle Dissipation in a Superconducting Artificial Atom — •Ioan Pop — Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — Department of Applied Physics, Yale University, New Haven, CT 06520, USA

We demonstrate immunity to quasiparticle dissipation in a Josephson junction. At the foundation of this protection rests a prediction by Brian Josephson from fifty years ago: the particle-hole interference of superconducting quasiparticles when tunneling across a Josephson junction [1]. The junction under study is the central element of a fluxonium artificial atom, which we place in an extremely low loss environment and measure using radio-frequency dispersive techniques [2]. Furthermore, by using a quantum limited amplifier (a Josephson Parametric Converter) we can observe quantum jumps between the 0 and 1 states of the qubit in thermal equilibrium with the environment. The distribution of the times in-between the quantum jumps reveals quantitative information about the population and dynamics of quasiparticles[3]. The data is entirely consistent with the hypothesis that our system is sensitive to single quasiparticle excitations, which opens new perspectives for quasiparticle monitoring in low temperature devices.

[1] B. D. Josephson, Physics Letters **1**, 251 (1962)
[2] I. M. Pop et al., Nature **508** (2014)
[3] U. Vool et al., PRL **113** (2014)

MA 6.8 Mon 12:00 H22

Tunable superconducting resonators with integrated trap structures for coupling with ultracold atomic gases — •Benedikt Ferdinand[1], Daniel Bothner[1,2], Dominik Wiedmaier[1], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalisches Institut and Center for Quantum Science (CQ) in LISA$^+$, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA, Delft, The Netherlands

We intend to investigate a hybrid quantum system where ultracold atomic gases play the role of a long-living quantum memory, coupled to a superconducting qubit via a coplanar waveguide transmission line resonator. As a first step we developed a resonator chip containing a Z-shaped trapping wire for the atom trap. In order to suppress parasitic resonances due to stray capacitances, and to achieve good ground connection we use hybrid superconductor - normal conductor chips. As an additional degree of freedom we add a ferroelectric capacitor making the resonators voltage-tunable. We furthermore show theoretical results on the expected coupling strength between resonator and atomic cloud.

MA 6.9 Mon 12:15 H22

Quantum correlations in microwave frequency combs — •Thomas Weissl[1], Erik Tholén[2], Daniel Forchheimer[1,2], and David B. Haviland[1] — [1]KTH- Royal Institute of Technology, 106 91 Stockholm, Sweden — [2]Intermodulation Products AB, 823 93 Segersta, Sweden

Non-linear superconducting resonators are used as parametric amplifiers in circuit quantum electrodynamics experiments [1]. When pumped below threshold the pump correlates vacuum fluctuations in the signal and idler bands giving rise to two-mode squeezed vacuum. When a non-linear oscillator is pumped with a frequency comb complex multipartite entangled states can be created as demonstrated in similar experiments in the optical domain [2]. We present a method to generate and measure microwave frequency combs by up- and down-conversion from intermediate frequencies. The comb is generated and analyzed using a multi-frequency lock-in amplifier. From transmission measurements we extract correlation- and quasi-probability functions.

[1] E. Tholén et al., APL **90**, 253509 (2007)
[2] M. Chen et al., PRL **112**, 120505 (2014)

MA 6.10 Mon 12:30 H22

Microwave experiments with quantum phase-slip in superconducting AlO_x nanowires — •Sebastian T. Skacel[1], Marco Pfirrmann[1], Jan N. Voss[1], Micha Wildermuth[1], Julian Münzberg[1], Lucas Radtke[1], Sebastian Probst[1], Martin Weides[1,2], J. E. Mooij[1,3], Hannes Rotzinger[1], and Alexey V. Ustinov[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, D-76131 Karlsruhe, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, D-55128 Mainz, Germany — [3]Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands

Superconducting nanowires in the quantum phase slip (QPS) regime allow to study the flux and phase dynamics in duality to Josephson junction systems. We experimentally study QPS effects of nanowires which are embedded in a resonant microwave circuit. The samples are probed at ultra-low microwave power and applied magnetic field at mK temperatures. The AlO_x nanowires, with a sheet resistance in the kΩ range, are fabricated by sputter deposition of aluminium in a controlled oxygen atmosphere. The wires are defined with conventional electron beam lithography into hydrogen silsesquioxane (HSQ) down to a width of 15-30 nm.
We present the single layer process fabrication and measurements of nanowires galvanically coupled to a superconducting lumped element microwave resonator.

MA 6.11 Mon 12:45 H22

Localized quantum phase slips in TiN nanowires — •Ina Schneider[1], Tatyana Baturina[1,2], and Christoph Strunk[1] — [1]Inst. f. Exp. und Angewandte Physik, Uni Regensburg — [2]Inst. f. Semiconductor Physics, RAS, Novosibirsk, Russia

We investigate TiN nanowires with 780 nm length and widths ranging from 50-780 nm close to the superconductor/insulator transition. In zero magnetic field the superconducting transition of wider wires resembles that of macroscopic films, while narrower wires develop a finite and T-independent resistance down to the lowest temperatures. In perpendicular magnetic field B a pronounced nonmontonic magnetoresistance occurs. The $R(T)$-curves at fixed B show a reentrant insulating behavior very similar to that of Coulomb-blockaded linear arrays of Josephson junctions [1].

The $I(V)$-characteristics display a characteristic cross-over from the dc-Josephson effect towards Coulomb blockade at very low voltages and temperatures within a globally superconductive-like $I(V)$. In the linear regime, the magnetoresistance displays strong fluctuations. We interpret our results in terms of disordered Josephson networks with a B-dependent Josephson coupling energy that favors coherent quantum phase slips at certain B.

[1] A. Ergül, et al., NJP **15**, 095014 (2014).

MA 7: Transport: Topological Insulators - 2D (Joint session of DS, HL, MA, O and TT organized by TT)

Time: Monday 15:00–17:45 Location: H18

MA 7.1 Mon 15:00 H18

Probing the spin texture of generic helical edge states with an antidot — •Alexia Rod[1,2], Giacomo Dolcetto[1], Thomas L. Schmidt[1], and Stephan Rachel[2] — [1]Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg — [2]Institut für Theoretische Physik, TU Dresden, Germany

Edge states of time-reversal topological insulators are generally described as helical edge states, where the spin-axis symmetry is conserved. However, this symmetry is usually not guaranteed in experimental realizations. In its absence, the most general model to describe edge states is called generic helical liquid. Using this framework, a rotation of the spin quantization axis has been predicted, independently of the microscopic model and of the considered geometry [1, 2].

Here we propose a scheme to probe the spin texture of the edge states on a transport device. We investigate the transport properties of generic helical edge states in a two-dimensional topological insulator bar with an antidot in its center. We show that the conductance is implicitly dependent of the spin texture in the case of uniform bulk or structural inversion asymmetry. We also study sequential tunneling and cotunneling in presence of Coulomb interaction due to electron confinement on the antidot.

[1] T.L. Schmidt, S. Rachel, F. von Oppen, L. Glazman, PRL **108**, 156402 (2012).
[2] A. Rod, T.L. Schmidt, S. Rachel, PRB **91**, 245112 (2015).

MA 7.2 Mon 15:15 H18

Electron quantum optics in 2d topological insulators — •Andrea Spichtinger, Sven Essert, Viktor Krückl, and Klaus

Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Besides conventional quantum Hall systems [1], 2d topological insulators (TIs) are ideal systems providing ballistic channels for guiding charge carriers along edge states allowing for the study of two-particle interferometric effects. Employing wave-packet approaches we investigate correlations between indistinguishable spin pairs at opposite quantum spin Hall edges. Interconnecting opposite edges at TI constrictions or through quantum dots acting as "beam splitter" allows for realizing fermionic analogues of the famous photonic Hong-Ou-Mandel (HOM) effect. In particular, we will consider generalizations of the HOM effect since the dwell time of the quantum dot enters as a new timescale into HOM physics.

[1] E. Bocquillon et al., Ann. Phys. **526**, 1 (2014)

MA 7.3 Mon 15:30 H18

Transport in quantum spin Hall systems in parallel magnetic fields — •Michael Wimmer[1], Rafal Skolasinski[1], Dmitry Pikulin[2], and Jason Alicea[3] — [1]TU Delft, The Netherlands — [2]University of British Columbia, Canada — [3]Caltech, US

Edge states in quantum spin Hall (QSH) systems are protected by time-reversal symmetry, resulting in a qunatized conductance. A magnetic field breaks that protection, and should lead to a deviation from perfect quantization. We will discuss generic features of semiconductor-based QSH systems (such as HgTe/CdTe and InAs/GaSb) that affect the magnetic field dependence of edge state conductance, focusing on the effect of an in-plane field.

MA 7.4 Mon 15:45 H18

Spectral functions of the correlated topological insulator — •Damian Zdulski and Krzysztof Byczuk — Faculty of Physics, Institute of Theoretical Physics, University of Warsaw, ul.Pasteura 5, PL-02-093 Warsaw, Poland

In our recent paper [1], we have studied the influence of electron correlations on topological insulators (TIs) at finite temperatures. The correlated TI was represented by the Kane-Mele model with the interaction term as in the Falicov-Kimball model and it was examined within the Hartree and the Hubbard I approximations. In this talk, we will present extension of that analysis by investigating properties of the system within the dynamical mean field approximation. Our findings show that dynamical correlations yield totally new structures, which are seen in the the momentum dependent spectral functions. Namely, we see: 1) widening of Dirac nodes over finite range of **k** points in the Brillouin zone (BZ), 2) creation of almost flat subbands in a finite range of the BZ, 3) appearance of kinks, and 4) splitting of kinks with formation of overlapping bands.

[1] D. Zdulski, K. Byczuk, PRB **92**, 125102 (2015)

MA 7.5 Mon 16:00 H18

The topological Anderson insulator phase in the Kane-Mele model — Christoph P. Orth[1], •Tibor Sekera[1], Christoph Bruder[1], and Thomas L. Schmidt[2] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg

It has been proposed that adding disorder to a topologically trivial mercury telluride/cadmium telluride (HgTe/CdTe) quantum well can induce a transition to a topologically nontrivial state. The resulting state was termed topological Anderson insulator and was found in computer simulations of the Bernevig-Hughes-Zhang model.

We show that the topological Anderson insulator is a more universal phenomenon and also appears in the Kane-Mele model of topological insulators on a honeycomb lattice. We numerically investigate the interplay between the parameters characterizing intrinsic spin-orbit coupling, extrinsic Rashba spin-orbit coupling and staggered sublattice potential. We establish the parameter regimes in which the topological Anderson insulator is found. For weak enough disorder, a calculation based on the lowest-order Born approximation reproduces the numerical data. Our results thus considerably increase the number of candidate materials for the topological Anderson insulator phase.

15 min. break

MA 7.6 Mon 16:30 H18

Interplay of topology and interactions in the quantum Hall regime of topological insulators: spontaneous symmetry breaking, tunable strongly interacting Luttinger liquid — •Stefan Jürgens, Maxim Kharitonov, and Björn Trauzettel — Institute of Theoretical Physics, University of Würzburg, Germany

We consider a class of two-dimensional topological insulators, in which the single-particle edge states are preserved in the presence of the magnetic field by a symmetry (such as crystalline) other than time-reversal, relevant to such materials as HgTe-type heterostructures.

We focus on the vicinity of the topological crossing point between two Landau levels. At half-filling, Coulomb interactions lead to the formation of the quantum Hall "ferromagnetic" many-body state with gapped charge excitations in the bulk. We derive and analyze the σ-model that describes the low-energy properties of this strongly interacting state, including the effect of the edge. We obtain the bulk phase diagram and find three phases, two with preserved and one with spontaneously broken U(1) symmetry. We study the collective edge charge excitations of these phases.

We demonstrate that in one of the phases with preserved U(1) symmetry, the edge charge excitations are gapless and described by a highly tunable, strongly interacting Luttinger liquid. When U(1) symmetry is broken in this phase, edge excitations become gapped and are described by a sine-Gordon model. Our main conclusion is that continuous U(1) symmetry is a necessary condition for the existence of the gapless edge excitations in this strongly interacting system.

MA 7.7 Mon 16:45 H18

Terahertz properties of Dirac electrons and holes in HgTe films with critical thickness — •Uladzislau Dziom[1], Alexey Shuvaev[1], Nikolai Mikhailov[2], Ze Don Kvon[2], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Novosibirsk State University, Novosibirsk 630090, Russia

We present and discuss properties of mercury telluride (HgTe) films with critical thickness in far-infrared (THz) spectral range. Density of charge carriers is controlled, using contact-free optical gating by visible light. Transmission measurements in applied magnetic field demonstrate switching from hole to electron-like behavior, as illumination time increases. The cyclotron mass of the electrons, extracted from the data, shows a square root dependence upon the charge concentration in a broad range of parameters. This can be interpreted as a clear proof of a linear dispersion relations, i.e. Dirac-type charge carriers.

MA 7.8 Mon 17:00 H18

Topological Edge States with Zero Hall Conductivity in a Dimerized Hofstadter Model — •Alexander Lau[1], Carmine Ortix[1,2], and Jeroen van den Brink[1,3] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Institute for Theoretical Physics, Utrecht University, The Netherlands — [3]Department of Physics, TU Dresden, Germany

The Hofstadter model is one of the most celebrated models for the study of topological properties of matter and allows the study of the quantum Hall effect in a lattice system. Indeed, the Hofstadter Hamiltonian harbors the topological chiral edge states that are responsible for the quantized Hall conductivity.

Here, we show that a lattice dimerization in the Hofstadtermodel opens an energy gap at half-filling. What is more, we demonstrate that even if the ensuing insulator has a Chern number equal to zero, concomitantly a doublet of edge states appear that are pinned to specific momenta. We show that the presence of these states can be understood from the topological properties of lower dimensional cuts of the system, using a mapping of the Hofstadter Hamiltonian to a collection of one-dimensional Aubry-Andre-Harper (AAH) models. A sub-set of AAH chains in this collection preserve inversion symmetry. This guarantees the presence of topologically protected doublets of end modes to which the edge states are pinned. To explicitly prove the robustness of the emerging edge states, we define and calculate the topological invariant that protects them, which turns out to be an integer invariant for inversion-symmetric AAH models.

MA 7.9 Mon 17:15 H18

Disorder induced zero Landau level in topological insulator nanowires and its signature in conductance fluctuations — •Emmanouil Xypakis and Jens H Bardarson — Max-Planck-Institut f. Physik komplexer Systeme Noethnitzer Str. 38, 01187 Dresden, Germany

In this talk I will discuss the quantum transport properties of a disordered topological insulator in a strong magnetic field. The focus is on the case when the chemical potential is close to the Dirac point, where the transport is dominated by induced chiral modes. Disorder has a drastic role in the system electrical response by revealing a zero Landau level, which is absent for clean topological insulators. We study the dependence of the zero Landau level energy window on the system parameters, such as system size, disorder and magnetic field strength.

MA 7.10 Mon 17:30 H18

Time-resolved pure spin fractionalization and spin-charge separation in helical Luttinger liquid based devices — •Giacomo Dolcetto[1,2], Matteo Carrega[2], Alessio Calzona[2,3], and Maura Sassetti[2,3] — [1]Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg — [2]SPIN-CNR, Genova, Italy — [3]Dipartimento di Fisica, Università di Genova, Italy

Helical Luttinger liquids, appearing at the edge of two-dimensional topological insulators, represent a new paradigm of one-dimensional systems, where peculiar quantum phenomena can be investigated [1]. Motivated by recent experiments on charge fractionalization [2], we propose a setup based on helical Luttinger liquids that allows one to time-resolve, in addition to charge fractionalization, also spin-charge separation and pure spin fractionalization. This is due to the combined presence of spin-momentum locking and interactions. We show that electric time-resolved measurements can reveal both charge and spin properties, avoiding the need of magnetic materials [3, 4]. Although challenging, the proposed setup could be achieved with present-day technologies, promoting helical liquids as interesting playgrounds to explore the effects of interactions in one dimension.

[1] G. Dolcetto, M. Sassetti, and T. L. Schmidt, arXiv preprint arXiv:1511.06141
[2] H. Kamata, N. Kumada, M. Hashisaka, K. Muraki, and T. Fujisawa, Nat. Nanotechnol. **9**, 177 (2014)
[3] A. Calzona, M. Carrega, G. Dolcetto, and M. Sassetti, Physica E **74**, 630 (2015)
[4] A. Calzona, M. Carrega, G. Dolcetto, and M. Sassetti, PRB **92**, 195414 (2015)

MA 8: Magnetic Surface Excitations

Time: Monday 15:00–17:30 Location: S052

Invited Talk MA 8.1 Mon 15:00 S052

Excitations and dynamics of non-collinear magnetization states in tailored adatom arrays — •Jens Wiebe — Department of Physics, Universität Hamburg, D-20355 Hamburg, Germany

Arrays of magnetic atoms adsorbed on the surface of a non-magnetic metal can be tailored in topology [1], magnetic anisotropy [2,3], interactions [1,4], and Kondo coupling [3] by combining different substrate/adatom species with the manipulation- [1], spin-resolved- [5] and inelastic- [6] spectroscopy capabilities of the scanning tunneling microscope. Such arrays are perfect model systems to study the complex phase diagram of strongly correlated multi-orbital electron systems. Here, I will focus on the rich physics we recently discovered in arrays of iron adatoms on platinum(111) [2,3,7]. This system can be theoretically described within the Hund's metal framework. We can tune the individual constituents, the Hund's impurities, from a regime of emergent magnetism to a multi-orbital Kondo state [3]. By coupling a few Hund's impurities to arrays, we find non-collinear ground states induced by the substrate mediated Ruderman-Kittel-Kasuya-Yosida interaction [7]. I will present our investigation of the excitations and dynamics of such non-collinear magnetization states.

[1] A. A. Khajetoorians *et al.*, Nat. Phys. **8**, 497 (2012). [2] A. A. Khajetoorians *et al.*, PRL **111**, 157204 (2013). [3] A. A. Khajetoorians *et al.*, Nat. Nano. **10**, 958 (2015). [4] L. Zhou *et al.*, Nat. Phys. **6** 187 (2010). [5] J. Wiebe *et al.*, JPD **44**, 464009 (2011). [6] A. A. Khajetoorians *et al.*, Nature **467**, 1084 (2010). [7] A. A. Khajetoorians *et al.*, Nat. Comm., (accepted, 2015).

MA 8.2 Mon 15:30 S052

Origin of inelastic excitations in rare-earth based metal-organic complexes — •Daniela Rolf[1], Matthias Bernien[1], Paul Stoll[1], Qingyu Xu[1], Fabian Nickel[1], Claudia Hartmann[1], Tobias R. Umbach[1], Jens Kopprasch[1], Janina N. Ladenthin[1], Enrico Schierle[2], Eugen Weschke[2], Constantin Czekelius[3], Wolfgang Kuch[1], and Katharina J. Franke[1] — [1]Freie Universität Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [3]Heinrich-Heine-Universität Düsseldorf, Germany

Rare-earth atoms with a partially filled f shell exhibit interesting magnetic properties due to their large magnetic anisotropy. Within the Dysprosium-tris(1,1,1-trifluoro-4-(2-thienyl)-2,4-butanedionate) ($Dy(tta)_3$) complex, Dy exhibits a total angular momentum of J = 15/2 with anisotropy-split M_J levels. Employing low-temperature STM we show that deposition of $Dy(tta)_3$ on a Au(111) surface leads to densely packed self-assembled islands. XMCD measurements on $Dy(tta)_3$ show a sizeable magnetic anisotropy. dI/dV-spectra on these molecules exhibit symmetric steps at $\pm$7.6 meV, which correspond to an inelastic excitation. To identify the origin of this feature unambiguously, we compare to spectra taken on the isostructural $Gd(tta)_3$, showing an inelastic step at a similar energy. As Gd^{3+} has a half-filled f shell, it is not expected to show any magnetic anisotropy. Hence, we conclude that the inelastic steps do not arise due to transitions between the anisotropy-split spin states, but can be explained by the excitation of molecular vibrations.

MA 8.3 Mon 15:45 S052

Tuning the Kondo coupling strength of a single molecule — •Olof Peters[1], Benjamin W. Heinrich[1], Christian Lotze[1], Xianwen Chen[1], Markus Ternes[2], and Katharina J. Franke[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Max-Planck Institut for Solid State Research, Stuttgart, Germany

Metal adatoms on a metal surface are typically strongly Kondo coupled, leading to a high Kondo temperature T_K, whereas insulating films efficiently reduce the coupling of such adsorbates resulting in much lower T_K. This decoupling gives the opportunity to study the Kondo effect with today's accessible magnetic fields and temperature ranges. A disadvantage of these isolating layers is the fixed coupling constant determined by the specific system.
We report on the controllable, continuous and reversible tuning of the Kondo coupling between a metal-organic complex (Fe-octaethylporphyrin-Cl) and its underlying Au(111) metal surface under the influence of a scanning tunnelling microscope tip at 1.1 K. Upon approach of the STM tip to the Fe core, the magnetic anisotropy increases and eventually a Kondo resonance appears. The Kondo coupling strength continuously increases at further tip approach.
We ascribe these results to a modification of the crystal field by the tip leading to a shift in the d-level energies. The change in crystal field also results in a relaxation of the Fe atom towards the substrate thus tuning the magnetic interactions from weak into the strong Kondo coupling regime.

MA 8.4 Mon 16:00 S052

Reversible switching of the Kondo effect at a giant Rashba surface — •Jens Kügel, Andreas Krönlein, and Matthias Bode — Experimentelle Physik II, Würzburg, Germany

Transition metal phthalocyanine (TMPc) molecules on metal substrate have recently attracted considerable interest, as they offer a versatile platform to study and the tune magnetic interaction of the central metal ion with the substrate's conduction electrons [1,2]. Especially the Kondo effect arising from unscreened magnetic moments of the metal ion has been intensively studied [3,4].

In this contribution we present a low-temperature ($T = 5$ K) scanning tunneling microscopy and spectroscopy (STS) study of single MnPc molecules adsorbed on $BiAg_2$, a surface alloy which has been shown to exhibit a giant Rashba effect [5]. We will show that a STS feature close to the Fermi energy —most likely a signature of Kondo screening— can be reversible switched on and off by controlled manipulation with the STM tip.

[1] A. Zhao *et al.*, Science **309**, 1542 (2005).
[2] J. Kügel *et al.*, Phys. Rev. B **91**, 235130 (2015).
[3] D. Rakhmilevitch *et al.*, Phys. Rev. Lett. **113**, 236603 (2014).
[4] A. Strozecka *et al.*, Phys. Rev. Lett. **109**, 147202 (2012).
[5] C. R. Ast *et al.*, Phys. Rev. Lett. **98**, 186807 (2007).

MA 8.5 Mon 16:15 S052

Tailoring the magnetic ground state of a two-molecule Kondo system by chemical interactions — •T. Esat[1], B. Lechtenberg[2], T. Deilmann[3], C. Wagner[1], P. Krüger[3], R. Temirov[1], M. Rohlfing[3], F.B. Anders[2], and F.S. Tautz[1] — [1]Peter Grünberg Institute (PGI-3), FZ Jülich, Germany — [2]Institut für Festkörpertheorie, Universität Münster, Germany — [3]Lehrstuhl für Theoretische Physik II, TU Dortmund, Germany

Molecules are considered to be a promising platform for spintronics since self-assembly offers the opportunity to create tailored arrays of single spins. In this context, engineering the interaction between spins is crucial for future applications.

Rather than relying on the magnetic exchange interaction to tailor the magnetic properties of a nanostructure, we propose a novel approach to achieve the same goal: it relies on the systematic use of the ubiquitous non-magnetic chemical interaction between the constituents of the nanostructure. Our approach is crucially based on spin-moment carrying orbitals that are extended in space [1] and therefore allow the direct coupling of magnetic properties to wave function overlap, i.e. the formation of chemically bonding and anti-bonding orbitals. We demonstrate the approach for a dimer of metal-molecule complexes on the Au(111) surface. Changing the wave function overlap between the two monomers, we tune the dimer through a quantum phase transition from a triplet to a singlet ground state, with one configuration being located extremely close to a quantum critical point.

[1] T. Esat et al., Phys. Rev. B 91, 144415 (2015)

MA 8.6 Mon 16:30 S052

The effect of surface oxidation on spin scattering for the W(110) surface — •Stephan Borek[1], Jürgen Braun[1], Jan Minár[1,2], Dima Kutnyakhov[3], Hans-Joachim Elmers[3], Gerd Schönhense[3], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]University of West Bohemia Pilsen — [3]Johannes-Gutenberg-Universität Mainz

It is well known that the W(110) surface possess interesting properties due to spin-orbit induced splitting of surface states. In our work we investigated the spin-orbit induced scattering of electrons from a clean W(110) surface using corresponding diffraction patterns to get an overview on the scattering behaviour. It was found that an oxygen passivation of the W(110) surface with a full oxygen overlayer has a huge impact on the electron diffraction. The oxidation of the W(110) surface reduces the spin-orbit asymmetry and the figure of merit whereas the reflectivity is increased. To investigate the surface electronic structure we calculated angle-resolved photoemission spectra using the fully-relativistic one-step model. Additionally, we will discuss the impact of full potential calculations on the spin-resolved diffraction patterns of spin-polarized electrons.

MA 8.7 Mon 16:45 S052

Tuning magnetic coupling between organic-metal hybrids mediated by a nanoskyrmion lattice — •Maciej Bazarnik[1], Jens Brede[2], and Roland Wiesendanger[1] — [1]Dept. of Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany — [2]Donostia International Physics Center, Paseo Manuel de Lardizabal 4 20018 Donostia - San Sebastian, Spain

Molecular spintronic devices offer great potential for future energy-efficient information technology as they combine ultimately small size, high-speed operation, and low-power consumption. There are two approaches to molecular spintronics: first, to utilize the intrinsic properties of molecules by depositing them on weakly interacting surfaces like thin film insulators, graphene, or gold; second, to make use of new properties of organic-metal hybrids created by strong hybridization of molecular orbitals with the substrate such as iron films on iridium [1].

Here, we take the latter approach to control the magnetic properties of organic-metal hybrids and tune the magnetic coupling. We show how to position fullerene molecules on the skyrmionic lattice of a single atomic layer of iron on an iridium substrate utilizing the STM-based atomic manipulation techniques, in order to tune the magnetic interactions between them.

[1] J. Brede *et al.* Nature Nano. 9 (2014) 1018-1023

MA 8.8 Mon 17:00 S052

Spin manipulation by creation of single-molecule radical cations — •Sujoy Karan[1,2], Na Li[3], Yajie Zhang[4], Yang He[3], I-Po Hong[3], Huanjun Song[4], Jing-Tao Lü[5], Yongfeng Wang[1,3], Lianmao Peng[3], Kai Wu[4], Georg S. Michelitsch[6], Reinhard J. Maurer[6], Katharina Diller[6], Karsten Reuter[6], Alexander Weismann[1], and Richard Berndt[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93053 Regensburg, Germany — [3]Key Laboratory for the Physics and Chemistry of Nanodevices, Department of Electronics, Peking University, Beijing 100871, P. R. China — [4]College of Chemistry and Molecular Engineering, Peking University, Beijing 100871, P. R. China — [5]School of Physics, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan 430074, P. R. China — [6]Lehrstuhl für Theoretische Chemie, Technische Universität München, 85747 Garching, Germany

All-trans-retinoic acid (ReA), a closed-shell organic molecule comprising only C, H, and O atoms, is investigated on a Au(111) substrate using scanning tunneling microscopy and spectroscopy. In dense arrays single ReA molecules are switched to a number of states, few of which carry a localized spin as evidenced by conductance spectroscopy in high magnetic fields. The spin of a single molecule may be reversibly switched on and off without affecting its neighbors. We suggest that ReA on Au is readily converted to a radical by the abstraction of an electron.

MA 8.9 Mon 17:15 S052

Enantiomer-dependent spin orientation in photoelectron transmission through heptahelicene molecules — •Matthias Kettner[1], Johannes Seibel[2], Daniel Nürenberg[1], Karl-Heinz Ernst[2], and Helmut Zacharias[1] — [1]University of Münster, Center for Soft Nanoscience and Physikalisches Institut, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany — [2]EMPA, Nanoscale Materials Science, Überlandstrasse 129, 8600 Dübendorf, Switzerland

The interaction of electrons with helical molecules attains growing interest due to a spin selectivity in electron transmission. Experiments on self-assembled monolayers of double stranded DNA and oligopeptides [1] 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 different metal single crystal surfaces. The molecules arrange themselves to a highly ordered monolayer [2]. Samples are then irradiated with $\lambda = 213$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 Mott scattering. The sign of the spin polarization depends on the helicity of the enantiomer. The effect of the heptahelicene on the spin orientation seems to be independent on the substrate.

References
[1] Kettner, M. et al., J.Phys.Chem. C 2014, 119, 26
[2] Seibel, J. et al., J.Phys.Chem. C 2014, 118, 29135

MA 9: Spincaloric Transport (jointly with TT)

Time: Monday 15:00–18:15 Location: H31

MA 9.1 Mon 15:00 H31

Spectral characteristics of time resolved magnonic spin Seebeck effect [1] — •levan chotorlishvili, seyyed etesami, and jamal berakdar — Institut für Physik, Martin Luther University Halle-Wittenberg, 06099 Halle/Saale, Germany

Spin Seebeck effect (SSE) refers to the generation of spin current due to a temperature gradient, in analogy to the conventional Seebek effect. The current work addresses and unvocer the role of subthermal magnons contributions to the SSE in insulating ferromagnets. The finding is in line with recent experiments given in Ref. [2], and points to further interesting experiments and material composition design aiming at enhancing/exploiting SSE. Technically, the spin-current dynamics is treated based on the Landau-Lifshitz-Gilbert (LLG) equation, while the formation of the time dependent thermal gradient being described self-consistently via the heat equation coupled to the magnetization dynamics. [3]

[1] S. R. Etesami, L. Chotorlishvili, and J. Berakdar, Appl. Phys. Lett. 107, 132402 (2015). [2] S. R. Boona and J. P. Heremans, Phys. Rev. B 90, 064421 (2014). [3] N. Roschewsky, M. Schreier, A. Kamra, F. Schade, K. Ganzhorn, S. Meyer, H. Huebl, S. Geprgs, R. Gross, and S. T. B. Goennenwein, Appl. Phys. Lett. 104, 202410 (2014).

MA 9.2 Mon 15:15 H31

A novel tool to investigate anisotropic effects in spin caloric measurements — •Oliver Reimer, Michel Bovender, Jan-Oliver Dreessen, Daniel Meier, Lars Helmich, Andreas Hütten, Jan-Michael Schmalhorst, Günter Reiss und Timo Kuschel — CSMD, Physics Department, Bielefeld University, Germany

In spin caloric measurements ∇T acts as a driving force for spin currents. A ferromagnet exposed to ∇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. In paramagnets the spin Nernst effect is expected to cause a transverse spin current which can induce a spin torque transfer at the interface to a magnetic material. Thus, ∇T could be used in combination with $\vec{H}$ to create a spin Nernst effect based magnetothermopower similar to the current driven spin Hall magnetoresistance [2,3]. We introduce a new setup which allows the rotation of ∇T in addition to varying T_{base} and ΔT. This talk gives an overview of the implementation of an infrared camera controlled rotation of ∇T which combined with the rotation of $\vec{H}$ enables the measurement of anisotropic spin caloric effects. The functionality of the setup is proven by planar Nernst effect measurements and compared to the results of D. Meier et al. [4].

[1] K. Uchida et al., Appl. Phys. Lett. 97, 172505 (2010)
[2] H. Nakayama et al., Phys. Rev. Lett. 110, 206601 (2013)
[3] M. Althammer et al., Phys. Rev. B 87, 224401 (2013)
[4] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 9.3 Mon 15:30 H31

Tunnel magneto-Seebeck effect in MgO tunnel junctions — •Ulrike Martens[1], Alexander Boehnke[2], Marvin von der Ehe[1], Christian Franz[3], Michael Czerner[3], Karsten Rott[2], Andy Thomas[2,4], Christian Heiliger[3], Günter Reiss[2], and Markus Münzenberg[1] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Germany — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Justus-Liebig-Universität Gießen, Germany — [4]IMW, IFW Dresden, Germany

In recent spincaloritronic research several groups have observed the tunnel magneto-Seebeck effect (TMS) in magnetic tunnel junctions (MTJs) incorporating CoFe electrodes and MgO tunnel barriers [1, 2]. Semiconducting materials are known to have large Seebeck coefficients. This is mainly attributed to the gap in their band structure and the asymmetric position of the Fermi-level. The tunnel magneto-Seebeck effect (TMS) is a powerful tool to investigate such spin-dependent Seebeck coefficients, because separate spin-channels can be defined in magnetic tunnel junctions (MTJs). Here, we investigate the spin-dependent Seebeck coefficients of CoFeB/MgO/CoFeB MTJs with different thicknesses of the MgO barrier. CoFeB/MgO/CoFeB MTJs with TMR ratios of 80% to 230% show TMS ratios of 5% to 50%. With a size variation of the heating laser spot we see zero crossing voltage compensation effects. Funding by DFG SPP 1538 is acknowledged.

[1] Walter, M., et al. Nature Mater. 10, 742 (2011)
[2] Liebing, N., et al. Phys. Rev. Lett. 107, 177201 (2011)
[3] A. Boehnke et al. Rev.Sci. Instrum 84 (2013)

MA 9.4 Mon 15:45 H31

Spincaloric properties of epitaxial $Co_2MnSi/MgO/Co_2MnSi$ magnetic tunnel junctions — •Benjamin Geisler[1,2] and Peter Kratzer[2] — [1]FRM II, Technische Universität München, 85748 Garching, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

Magnetic tunnel junctions (MTJs) with ferromagnetic, half-metallic electrodes are interesting spintronics devices due to their high tunnel magnetoresistance ratio. If a thermal gradient is applied to such a MTJ, the relative electrode magnetization can be detected by measuring the induced voltage, i.e., by exploiting the magneto-Seebeck effect.

Here we present an *ab initio* viewpoint on transport and spincaloric properties of epitaxial $Co_2MnSi/MgO(001)/Co_2MnSi$ MTJs [Phys. Rev. B 92, 144418 (2015)]. We compare results calculated with the conventional Sivan-Imry approach to results obtained from solving the Landauer-Büttiker equation directly. The latter procedure circumvents the linear response approximation inherent in the Seebeck coefficient and provides the response of the system (current or voltage) to arbitrary thermal gradients. Moreover, thermal variations of the chemical potential in the leads and finite-bias effects can be readily included in this method. Especially the former are found to be important here for obtaining qualitatively correct results. We show how the spincaloric properties of the MTJs depend on the interface atomic structure and that they can be tailored by a targeted growth control. Finally, we shortly comment on the influence of thermally activated electrode phonons and interface magnons.

MA 9.5 Mon 16:00 H31

Current progress of the tunnel magneto-Seebeck effect in Heusler based MTJs — •Alexander Boehnke[1], Torsten Huebner[1], Ulrike Martens[2], Marvin von der Ehe[2], Christian Sterwerf[1], Christian Franz[3], Timo Kuschel[1], Andy Thomas[1,4], Christian Heiliger[3], Markus Münzenberg[2], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]University of Greifswald, Germany — [3]University of Giessen, Germany — [4]IMW, IFW Dresden, Germany

The tunnel magneto-Seebeck effect (TMS) [1,2] describes the difference of the Seebeck coefficients S_p and S_{ap} of a magnetic tunnel junction (MTJ) in the parallel and antiparallel magnetization alignment. Obviously, increasing the difference between S_p and S_{ap} as well as their magnitude is desirable to reduce the signal-to-noise ratio, e.g. for determining the magnetic state of the MTJ in memory applications.

Here, we suggest MTJs with an MgO barrier and Heusler compound electrodes (e.g. Co_2FeAl, Co_2FeSi) as good candidates for fulfilling both goals, because of their half-metallic density of states [3]. We will present current results on TMS measurements performed on these MTJs and discuss how to optimize the choice of materials for future devices.

[1] Walter et al., Nature Mater. 10, 742 (2011).
[2] Boehnke et al. Rev. Sci. Instrum. 84, 063905 (2013).
[3] Geisler et al., Phys. Rev. B. 92, 144418 (2015).

MA 9.6 Mon 16:15 H31

Comparison of laser induced and intrinsic tunnel magneto-Seebeck effect in $CoFeB/MgAl_2O_4/CoFeB$ magnetic tunnel junctions — •Torsten Huebner[1], Alexander Boehnke[1], Ulrike Martens[2], Markus Münzenberg[2], Andy Thomas[3], Timo Kuschel[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]IFP, Greifswald University, Germany — [3]IMW, IFW Dresden, Germany

The Seebeck coefficient of a Magnetic Tunnel Junction (MTJ) depends on its magnetic state known as the tunnel magneto-Seebeck (TMS) effect [1]. It has been extensively studied with indirect Joule and laser induced heating [2,3]. Zhang, Teixeira et al. [4,5] proposed a third method using the intrinsic Joule heating by the tunneling current without any external temperature gradient. Here, we prepared $CoFeB/MgAl_2O_4/CoFeB$ MTJs and obtained a maximum tunnel magneto-resistance (TMR) ratio of 34 % at room temperature for a nominal barrier thickness of 1.8 nm. We used a modulated diode laser (P_{max}=150 mW, λ=637 nm, f=177 Hz) to generate a temperature gradient across the junctions and recorded IU-characteristics to compare the laser induced TMS with the intrinsic TMS.

15 min. break

MA 9.7 Mon 16:45 H31

Influence of laser heating on switching fields in magnetic tunnel junctions — •Hangfu Yang, Niklas Liebing, Xiukun Hu, Sibylle Sievers, Mark Bieler, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The field of spin caloritronics focuses on the interplay between heat, charge and spin currents in magnetic systems and gained a lot of interest due to new phenomena such as the tunnel magneto-Seebeck effect [1] and the thermal spin transfer torque [2]. Here, we study the influence of temperature and temperature gradients on magnetic switching of the free layer of CoFeB/MgO/CoFeB magnetic tunnel junctions (MTJs). Thermal gradients across the MTJs are generated locally by femtosecond laser pulses. The switching of the free layer is determined by magnetostatic measurements of the critical switching curve as a function of the laser power. We find that the entire critical curve shifts up to 4 mT along the easy axis at a laser power of 110 mW. We show that the shift in the critical curve is caused by an increase of the overall temperature due to heat accumulation rather than by a temperature gradient. Future studies will focus on reducing the stationary temperature increase, allowing for the generation of larger temperature gradients in our samples.

[1] N. Liebing et al., Phys. Rev. Lett. 107, 177201 (2011); M. Walter et al., Nature Mater. 10, 742-746 (2011).

[2] M. Hatami et al., Phys. Rev. Lett. 99, 066603 (2007); G.M. Choi et al., Nature Phys. 11, 576-581 (2015).

MA 9.8 Mon 17:00 H31

Thickness-dependent low-temperature enhancement of the spin Seebeck effect in YIG films — •Joel Cramer[1], Er-Jia Guo[1,2], Andreas Kehlberger[1], Christoph Schneider[1], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Quantum Condensed Materials Division, Oak Ridge National Laboratory, TN 37830, Oak Ridge, USA

In ferromagnetic insulator (FMI)/normal metal (NM) bilayers the temperature dependence of the spin Seebeck effect (SSE) has been probed as a function of FMI thickness, different interfaces and detection materials [1, 2]. At low temperatures, an enhancement of the SSE signal is observed, including the appearance of a peak in the amplitude. This enhancement is more pronounced for thicker films and vanishes for film thicknesses below 600 nm. Furthermore, the temperature of the signal maximum strongly depends on the FMI thickness as well as on the FMI/NM interface. The thickness dependence can be well explained by considering a model of a magnon-driven SSE, which takes into account the frequency dependent propagation length of thermally excited magnons inside the bulk material. The NM dependence, however, indicates that previously neglected interface effects play a major role in the observed signal. In order to obtain a better understanding of the influence of the FMI/NM interface, transmission electron microscopy (TEM) measurements combined with elemental analysis (EELS) are performed. [1] A. Kehlberger et al. Phys. Rev. Lett. 115, 096602 (2015) [2] Er-Jia Guo et al. arXiv: 1506.06037

MA 9.9 Mon 17:15 H31

Static magnetic proximity effect in Pt layers on sputter deposited $NiFe_2O_4$ and on Fe of various thicknesses investigated by x-ray resonant magnetic reflectivity — •Panagiota Bougiatioti[1], Christoph Klewe[1], Olga Kuschel[2], Joachim Wollschläger[2], Laurence Bouchenoire[3,4], Simon D. Brown[3,4], Jan-Michael Schmalhorst[1], Daniel Meier[1], Günter Reiss[1], and Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Fachbereich Physik, Universität Osnabrück, Germany — [3]XMaS, ESRF, Grenoble, France — [4]University of Liverpool, UK

In this project we implemented x-ray resonant magnetic reflectivity (XRMR) to investigate magnetic proximity effects (MPE) in Pt films on sputter deposited $NiFe_2O_4$(260 nm) (NFO) and in Pt/Fe(x nm) samples with x from 1.1 nm to 18.2 nm. We did not observe a magnetic response down to a limit of 0.04 μ_B per Pt atom regarding the sputter deposited NFO bilayer, in agreement to previously investigated chemical vapor deposited NFO samples [1]. We performed longitudinal spin Seebeck effect measurements on this bilayer system and exclude an anomalous Nernst effect induced by the MPE in Pt down to a certain limit. Furthermore, we confirm the independence of the MPE from the thickness of the magnetic layer (Fe), unveiling its sensitivity to the interface properties of the magnetic material [2].

[1] T. Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)
[2] T. Kuschel et al., submitted to IEEE Trans. Magn. (2015)

MA 9.10 Mon 17:30 H31

Temperature dependence of the domain wall magneto-Seebeck effect — •Alexander Fernández Scarioni, Patryk Krzysteczko, Xiukun Hu, Niklas Liebing, Sibylle Sievers, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116, Braunschweig, Germany

We study the thermopower response of a magnetic domain wall in a nanowire under the influence of a thermal gradient and compare it with corresponding magnetoresistance measurements. The nanowire used is an L-shape permalloy (Ni80Fe20) nanowire. A single domain wall can be nucleated and pinned at a notch between two electrical contacts. We observe a clear thermopower signature of the domain wall pinned at the notch.

The thermal gradient is generated by an electrical microheater placed in the vicinity of the magnetic nanowire. We study the local heat distribution experimentally by microscopic resistance thermometers and numerically by finite element calculations.

By combination of thermal gradient and magnetothermopower measurements at various temperatures we can describe the system based on the anisotropic magneto-Seebeck effect.

MA 9.11 Mon 17:45 H31

Thermally excited magnon accumulation in complex magnetic materials — •Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — Universität Konstanz, Konstanz, Germany

It was shown experimentally that in a magnetic insulator spin currents can be created by applying temperature gradients [1]. Using atomistic spin model simulations, we study magnonic spin currents and their characteristic length scales in ferromagnetic materials with different temperature profiles [2,3,4]. Furthermore, we explore thermally excited spin currents in antiferromagnetic materials and study the magnon accumulation in the vicinity of a temperature step and its characteristic length scale. We determine the different antiferromagnetic modes that are excited and discuss their propagation length using an one-dimensional analytical model.

These methods can be extended for ferrimagnetic materials. In a two-sublattice ferrimagnet, we determine the thermally excited magnon accumulation due to a temperature step. We study the temperature dependence of the magnon accumulation in ferrimagnets and investigate under which condition the magnon accumulation in such systems vanishes.

We acknowledge financial support by the DFG through SFB 767 and through SPP "Spin Caloric Transport".

[1] K. Uchida et al, Appl. Phys. Lett. **97**, 172505 (2010)
[2] U. Ritzmann et al., Phys. Rev. B **89**, 024409 (2014)
[3] A. Kehlberger et al.,Phys. Rev. Lett. **115**, 096602 (2015)
[4] U. Ritzmann et al., Phys. Rev. B **92**, 174411(2015)

MA 9.12 Mon 18:00 H31

Spin wave scattering and localization effects due to defects in magnetic materials — •Martin Evers, Cord A. Müller, and Ulrich Nowak — University of Konstanz, 78457 Konstanz, Germany

From earlier studies of transport of particles and waves it is known that there are different transport regimes. E.g. in a perfect crystal transport will be ballistic, but one usually has to deal with some kind of imperfections that induce disorder in the system. As Anderson has shown in 1958 in case of phase coherent transport disorder can also lead to completely suppressed transport, known as Anderson localization [1]. For the case of spin waves this will lead to a vanishing magnon propagation length, even without any damping mechanism [2,3].

Within a classical spin model utilizing the Landau-Lifshitz-Gilbert equation we study coherent backscattering (CBS), which is a weak localization phenomena and therefore a precursor for Anderson localization, in 2D. Especially the influence of non-linearities, damping and the Dzyaloshinskii-Moriya interaction is investigated. We also find evidence for coherent forward scattering [4] of magnons in a quasi one-dimensional setting, providing a direct signal of Anderson localization and absence of thermalization.

[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)
[4] T. Micklitz et al., Phys. Rev. Lett. **112**, 110602 (2014)

MA 10: Thyssen-Krupp Electrical Steel Ph. D. Thesis Award (Dissertationspreis)

Die Arbeitsgemeinschaft Magnetismus der DPG schreibt jedes Jahr den mit 1000 € dotierten Thyssen-Krupp Electrical Steel Dissertationspreis aus, der auf der Frühjahrstagung der Sektion der Kondensierten Materie (SKM) der Deutschen Physikalischen Gesellschaft (DPG) vergeben wird. Ziel des Preises ist die Anerkennung herausragender Forschung im Rahmen einer Doktorarbeit und deren exzellente Vermittlung in Wort und Schrift. In dieser Sitzung stellen sich die Nominierten, die in die Endauswahl gekommen sind, jeweils in einem 20 minütigen Vortrag zu ihrer preiswürdigen Dissertation vor. Weitere Details zu den Vorträgen sind unter http://www.dpg-physik.de/dpg/gliederung/fv/ma zu finden.

Time: Monday 15:00–17:00 Location: H32

Presentations by the selected final four nominees

MA 11: Magnetic Thin Films I

Time: Monday 15:00–17:45 Location: H33

MA 11.1 Mon 15:00 H33

Characterization of Gadolinium Thin Films — •Marianne Bartke[1], Lars Hellmich[1], Jamileh Beik Mohammadi[2], Claudia Mewes[2], Tim Mewes[2], and Anderas Hütten[1] — [1]Department of Physics, Center for Spinelectronic Materials and Devices, University of Bielefeld, D-33615 Bielefeld, Germany — [2]Department of Physics and Astronomy, MINT Center, University of Alabama, Tuscaloosa, Alabama 35487, USA

Gadolinium is well-known as a promising material for magnetic refrigeration. It is ferromagnetic below its Curie temperature at 293K and strongly paramagnetic at higher temperatures. A comparatively high magneto-caloric effect can be observed in a temperature range around this Tc up to 300K. Gd bulk materials have been studied extensively in the last couple of years. However, to the best of the author's knowledge, studies on thin film samples have not been reported yet. We report on Gd thinfilm samples which were prepared by means of sputter deposition. The impact of substrate temperatures and application of buffer materials on the crystal lattice structure has been evaluated. Magnetic properties of these samples, particularly temperature-dependent effective magnetization, gyromagnetic ratio and Gilbert damping parameter have been investigated by means of ferromagnetic resonance (FMR), VSM and transport measurements. Thus optimal preparation conditions for promising magneto-caloric materials have been evaluated.

MA 11.2 Mon 15:15 H33

Physical and electronic characterization of nanostructured MnSi — •Nico Steinki[1], David Schroeter[1], Patryk Krzysteczko[2], Alexander Fernándes Scarioni[2], Hans Werner Schumacher[2], Stefan Süllow[1], and Dirk Menzel[1] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Physikalisch Technische Bundesanstalt, Braunschweig, Germany

The non-centrosymmetric B20 chiral magnet MnSi shows intriguing properties involving the existence of skyrmions. Recently, we have started production and physical characterization of MnSi thin film samples [1,2] revealing considerable changes in the magnetic phase diagram compared to bulk material [3]. To further characterize the skyrmionic phase in MnSi under geometrical constraints, we have proceeded by nanostructuring the MnSi thin films by electron beam lithography. In particular, Hall bar structures with different widths down to 100 nm have been produced. On these, we have measured the Hall effect and magnetoresistance between 1.5 and 80 K in a magnetic field up to 8 T, thus covering the temperature and field regime of the skyrmionic phase. Here, we will present first results regarding the characterization of the structures and the comparison in terms of the electronic transport properties between thin films and our nanostructures.

[1] J. Engelke et al., J. Phys. Soc. Jpn. **81**, 124709 (2012)
[2] J. Engelke et al., Phys. Rev. B **89**, 144413 (2014)
[3] D. Menzel et al., J. Kor. Phys. Soc. **62**, 1580 (2013)

MA 11.3 Mon 15:30 H33

Turn on/off the high-temperature ferromagnetism in Si1-xMnx thin films through Mn-ion implantation — •Parul Pandey[1], Vladimir Rylkov[2], Ye Yuan[1], Anna Semisalova[1], Vladimir Mikhalevskiy[3], Oleg Novodvorskii[3], Victor Tugushev[2], Manfred Helm[1], and Shengqiang Zhou[1] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]NRC Kurchatov Institute, Moscow, Russia — [3]ILIT RAS, Shatura, Russia

Silicon based alloys with Mn-ions exhibits complex electric and magnetic phenomena which have direct implications in the contemporary microelectronic technology. Though, Si1-xMnx shows high-temperature ferromagnetism (TC) at low Mn content x~0.05-0.1, but the small solubility of Mn in Si leads to the formation of MnSi1.7 nanoparticles, which drives the system in an inhomogeneous phase and makes it irrelevant for the technological applications. However, a high Mn content screens the precipitation of such inhomogeneous phases. In this context, a set of thin films of Si1-xMnx (x=0.44-0.57) were prepared by pulsed laser deposition technique on Al2O3 (0001) substrate. We have found room-temperature ferromagnetism and a large moment for Si0.43Mn0.57 film as compared to the rest of samples. But, surprisingly, TC of Si0.43Mn0.57 drastically decreases from 300K to 40K as the Mn content was increased in the film through the ion-implantation process. In contrast, the stoichiometric film Si0.5Mn0.5 exhibits a huge increase in the moment by one-order in magnitude (with TC from 50K to 300K) after Mn-ion implantation.

MA 11.4 Mon 15:45 H33

***c*-axis oriented MnBi thin Films with high anisotropy grown from a stoichiometric $Mn_{55}Bi_{45}$ target** — •Sareh Sabet, Erwin Hildebrandt, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

There is an increased interest in the intermetallic compound MnBi as rare-earth free permanent magnet candidate to be used in magneto-optical memory applications as well as the hard magnetic component in an exchange spring magnet. The usual approach for the growth of MnBi thin films is stacking of individual Mn and Bi layers. Here, we report the synthesis of fully *c*-axis oriented MnBi thin films with high anisotropy from a single target with $Mn_{55}Bi_{45}$ (at. %) composition. The films were grown by DC magnetron sputtering at room temperature onto quartz glass substrates. The ferromagnetic low-temperature phase (LTP) was formed by a subsequent *in-situ* annealing step in vacuum. The out-of-plane and in-plane coercivity increases as expected with temperature and reaches 12 kOe and 14 kOe at 300 K, respectively. The maximum saturation magnetization is about 600 emu/cm^3. We have estimated a lower bound for the uniaxial anisotropy to be around $1{\cdot}10^7$ erg/cm^3.

MA 11.5 Mon 16:00 H33

Fe-N phase diagram of MBE grown thin films — •Dominik Gölden, Erwin Hildebrandt, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

The iron nitride system has been widely investigated due to the large variety of mechanical, electrical, and magnetic properties of the different phases. We explored the phase diagram of Fe-N thin films grown by molecular beam epitaxy (MBE). At elevated temperatures around 350 °C, γ'-Fe_4N is the most stable phase. At low temperatures, α'-Fe_8N, ϵ-Fe_3N and FeN were obtained by varying the growth rate and the nitrogen supply. At identical growth conditions the choice of substrate materials results in preferential growth of different iron nitride phases. The structural and magnetic properties of the thin films were in agreement with bulk properties. α'-Fe_8N, which is not a real thermodynamical phase, could not be obtained without admixture of other Fe-N phases. No evidence for the ordered phase α''-$Fe_{16}N_2$ was found even when the Fe-N phase diagram was scanned by thin film deposition with high resolution. While γ'-Fe_4N related materials might be useful for spintronics, the Fe-N system is probably not suited for permanent magnetic materials due to the high volatility of N.

15 min. break

MA 11.6 Mon 16:30 H33

Structural, magnetic and electrical properties of sputter deposited Mn-Fe-Ga thin films — •Alessia Niesen, Christian Sterwerf, Manuel Glas, Jan-Michael Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Structural and magnetic properties of DC sputter deposited $Mn_{3-x}FeGa$ were investigated. The crystallinity of the Mn-Fe-Ga thin films (40 nm thick) was confirmed using XRD. XRR and AFM measurements were utilized to investigate the surface, roughness, thickness and density of the deposited Mn-Fe-Ga. Depending on the stoichiometry, the deposition temperature, as well as the used substrate ($SrTiO_3$ (001) and MgO (001)) or buffer layer (TiN) the Mn-Fe-Ga crystallizes in the cubic $D0_3$ or the tetragonally $D0_{22}$ distorted phase (c = 7.14 Å). The main drawback for applications is the island growth of the Mn-Fe-Ga, confirmed by AFM measurements. Low roughness (≤ 1nm) and the $D0_{22}$ phase was observed for each used deposition temperature and composition of the Mn-Fe-Ga on $SrTiO_3$. Strong PMA was confirmed via AHE and AGM measurements. Low saturation magnetization (M_s ≈ 200 kA/m) and high coercivity fields (Hc ≤ 2 T) in the oop direction can be reached by tuning the composition. TiN buffered $Mn_{2.7}Fe_{0.3}Ga$ revealed sharper switching of the magnetization compared to the unbuffered layers. XAS and XMCD measurements showed Mn-O at the interface due to the MgO capping and no Mn-O in the bulk. The XMCD spectra revealed ferromagnetic coupling between the Mn and the Fe atoms.

MA 11.7 Mon 16:45 H33

Interface effects in $La_{1/3}Sr_{2/3}FeO_3/La_{2/3}Sr_{1/3}MnO_3$ heterostructures — •Markus Waschk[1], Markus Schmitz[1], Alexander Weber[2], 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 at Heinz Maier-Leibnitz Zentrum MLZ, Forschungszentrum Jülich GmbH, Lichtenbergstr. 1, 85747 Garching, Germany

Transition metal oxides (TMO) show functionalities which make them promising candidates for sensors or devices in future information technologies, because of electronic correlations and/or ordering phenomena. Such devices will consist of heterostructures of different TMO's, where interfaces play a crucial role. Due to the sensitivity of TMO's to external parameters such as strain, and electronic doping, magnetic and electric fields, their properties are easily altered at the interface. We have chosen the system LSFO/LSMO on $SrTiO_3$ as a model system to study interfaces effects systematically. LSFO is an antiferromagnet, which shows a Verwey transition at the Neél and charge ordering temperature $T_V = T_N = T_{CO} = 200\,K$. The drastic increase in resistivity with decreasing temperature offers the opportunity to study the influence of the electronic structure of LSFO on the interfacial magnetization of the ferromagnet LSMO. We will present our oxide molecular beam epitaxy growth process and structural analysis. Particularly with regard to the magnetization profile, polarized neutron reflectometry results will be presented to explain the interface behavior of the system.

MA 11.8 Mon 17:00 H33

Growth of epitaxial thin films of Ir-based novel double-perovskites by pulsed laser deposition — •Supratik Dasgupta, Vikas Shabadi, Philipp Komissinskiy, and Lambert Alff — Institute of Material Science, Technische Universität Darmstadt, Germany

Double perovskites ($A_2BB'O_6$) with $3d$-$5d$ cations in their B-B'-sites have various interesting properties. Double perovskites with Cr at their B-site have received particular attention due to their high ferrimagnetic ordering temperature, T_c. So far, Sr_2CrOsO_6 has been reported to have the highest T_c of about 725 K [1]. Theoretical calculations have predicted that the compound Sr_2CrIrO_6 (SICO) might even have a higher T_c. In addition to the high T_c, SICO is expected to be a half-metallic material being of high interest for spintronic applications. However, the metastable compound SICO so far has not yet been synthesized. Here, we report the epitaxial growth of SICO by pulsed laser deposition (PLD). The choice of substrate has turned out to be the key parameter to obtain phase-pure thin films. [1] Y. Krockenberger *et al.*, Phys. Rev. B **75**, 020404(R) (2007).

MA 11.9 Mon 17:15 H33

Spectroscopy of quadratic magnetooptic tensor of Fe/MgO thin films — •Robin Silber[1,2], Jan Dušek[3], Lukáš Beran[3], Jaromír Pištora[1], Günter Reiss[2], Martin Veis[3], Timo Kuschel[2], and Jaroslav Hamrle[1] — [1]VSB - Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University in Prague, Czech Republic

The magnetooptic Kerr effect (MOKE) is a well known and very useful physical phenomenon. MOKE at single wavelength is broadly used for detailed characterization of magnetic materials [1]. MO spectroscopy on the other hand is powerful tool for probing the electronic structure of the magnetic material. Most of the MOKE techniques rely solely on effects linear in magnetization, assuming that contributions of higher order in magnetization are negligible. Here, we present a technique of quadratic MOKE (QMOKE) spectroscopy that is based on the 8-directional method [2]. QMOKE spectra of Fe thin films grown on MgO substrate were acquired. From these, further two complex spectra of the quadratic magnetooptic tensor [3,4] are yielded, using standard Yeh's 4×4 matrix calculations. Finally, comparison with ab initio calculations is discussed.

[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))
[4] J. Hamrle et al., J. Phys. D: Appl. Phys. 40, 1563 (2007)

MA 11.10 Mon 17:30 H33

Towards optically controlled magnetization reversal in ferromagnetic (Co/Pt)n and (Co/Pd)n multilayers — •Umut Parlak[1], Daniel Bürgler[1], Roman Adam[1], Gholamreza Shayeganrad[2], Shaukat Khan[2], and Claus M. Schneider[1] — [1]Peter Grünberg Institute, PGI-6, Research Centre Jülich, 52425 Jülich, Germany — [2]Center for Synchrotron Radiation (DELTA), TU Dortmund, 44227 Dortmund, Germany

Recent studies demonstrate that optical control of the magnetization state by femtosecond laser pulses is feasible in ferromagnetic layers [1] as well as ferrimagnetic rare earth compounds [2]. Moreover, this all-optical manipulation is reversible and reproducible. Nevertheless the optically induced magnetization reversal strongly depends on both material properties and laser beam parameters; e.g. polarization state, fluence and exposure time. Here we investigate the range of material and laser parameters that play a role for the switching process in ferromagnetic (Co/Pt)n and (Co/Pd)n multilayers. We use a laser oscillator and a laser amplifier both having a central wavelength of 800 nm, pulse duration of about 40 fs, and a repetition rate of 80 MHz and 1 kHz, respectively. Kerr and Faraday microscopies are employed to image the domain state before and after the laser exposure. Depending on the laser parameters, a laser-exposed area undergoes magnetization switching, demagnetization or other magnetic modifications.
[1] C. H. Lambert, et al. Science 345,6202 (2014)
[2] C. D. Stanciu, et al. Physical Review Letters 99,4 (2007)

MA 12: Transport: Quantum Coherence and Quantum Information Systems - Theory 1 (Joint session of HL, MA and TT organized by TT)

Time: Tuesday 9:30–12:45 Location: H22

MA 12.1 Tue 9:30 H22

Measurement-induced entanglement of two transmon qubits by a single photon — Christoph Ohm and •Fabian Hassler — JARA Institute for Quantum Information, RWTH Aachen University, 52056 Aachen

On-demand creation of entanglement between distant qubits is desirable for quantum communication devices but so far not available for superconducting qubits. We propose an entanglement scheme that allows for single-shot deterministic entanglement creation by detecting a single photon passing through a Mach-Zehnder interferometer with one transmon qubit in each arm. The entanglement production essentially relies on the fact that superconducting microwave structures allow to achieve strong coupling between the qubit and the photon. By detecting the photon via a photon counter, a parity measurement is implemented and the wave function of the two qubits is projected onto a maximally entangled state. Moreover, due to the indivisible nature of single photons, our scheme promises full security for entanglement-based quantum key distribution.

MA 12.2 Tue 9:45 H22

Quantum Chemistry on a Superconducting Quantum Processor — •Michael P. Kaicher[1], Frank K. Wilhelm[1], and Peter J. Love[2] — [1]Theoretical Physics, Saarland University, 66123 Saarbruecken, Germany — [2]Department of Physics and Astronomy, Tufts University, Medford, MA 02155, USA

Quantum chemistry is the most promising civilian application for quantum processors to date. We study its adaptation to superconducting (sc) quantum systems, computing the ground state energy of LiH through a variational hybrid quantum classical algorithm. We demonstrate how interactions native to sc qubits further reduce the amount of quantum resources needed, pushing sc architectures as a near-term candidate for simulations of more complex atoms/molecules.

MA 12.3 Tue 10:00 H22

Optimization of Quantum Microwave Photodetection for circuit QED applications — •Marius Schöndorf[1], Luke C. Govia[1,3], Maxim Vavilov[2], Robert McDermott[2], and Frank K. Wilhelm[1] — [1]Universität des Saarlandes, Saarbrücken, Deutschland — [2]University of Wisconsin, Madison, USA — [3]McGill University, Montreal, Canada

Superconducting qubits are a promising candidate architecture for quantum computing and information. Readout of the qubit state is an important step that has to be taken for realising quantum algorithms in experiment. Recently we presented a qubit readout scheme [1] using a device called Jospehson Photomultiplier (JPM) [2]. One main step in this architecture is to read out a light state of a transmission line with the JPM. In this work we present a guide how to tune the different parameters in the experiment to optimize the measurement efficiency. We use Input-Output Theory to look at a continuous driven transmission line as well as various pulse states. Using analytical and numerical mehtods, we calculate conditions on the different parameters to optimize the respective measurement.

[1] L. C. G. Govia et al., PRA **92**, 022335 (2015)
[2] Y.-F. Chen et al., PRL **107**, 217401 (2012)

MA 12.4 Tue 10:15 H22

Theory and practice of dressed coherent states in circuit QED — •Frank Wilhelm[1] and Luke C. G. Govia[1,2] — [1]Theoretical Physics, Saarland University, Campus E 2.6, 66123 Saarbrücken, Germany — [2]Department of Physics, McGill University, Montreal, Canada

In the dispersive regime of qubit-cavity coupling, classical cavity drive populates the cavity, but leaves the qubit state unaffected. However, the dispersive Hamiltonian is derived after both a frame transformation and an approximation. Therefore, to connect to external experimental devices, the inverse frame transformation from the dispersive frame back to the lab frame is necessary. We show that in the lab frame the system is best described by an entangled state known as the dressed coherent state, and thus even in the dispersive regime, entanglement is generated between the qubit and the cavity. Also, we show that further qubit evolution depends on both the amplitude and phase of the dressed coherent state. This provides a limitation to readout in the dispersive regime. We show that only in the limit of infinite measurement time is this protocol QND, as the formation of a dressed coherent state in the qubit-cavity system applies an effective rotation to the qubit state. We show how this rotation can be corrected by a unitary operation, leading to improved qubit initialization by measurement and unitary feedback.

[1] L. C. G. Govia and F.K. Wllhelm,
Phys. Rev. Appl. **4**, 054001 (2015)
[2] L. C.G. Govia and F.K. Wilhelm, arXiv: 1506.04997

MA 12.5 Tue 10:30 H22

Gradient optimization for analytic controls — •Elie Assémat[1], Shai Machnes[2], David Tannor[2], and Frank Wilhelm-Mauch[1] — [1]Saarland University, Saarbrücken, Germany — [2]Weizmann Institute of Science, Rehovot, Israël

Quantum optimal control becomes a necessary step in a growing number of studies in the quantum realm. Recent experimental advances showed that superconducting qubits can be controlled with an impressive accuracy. However, most of the standard optimal control algorithms are not designed to manage such high accuracy. To tackle this issue, a novel quantum optimal control algorithm have been introduced: the Gradient Optimization for Analytic conTrols (GOAT). It avoids the piecewise constant approximation of the control pulse used by standard algorithms. This allows an efficient implementation of very high accuracy optimization. It also includes a novel method to compute the gradient that provides many advantages, e.g. the absence of backpropagation or the natural route to optimize the robustness of the control pulses. This talk will present the GOAT algorithm and a few applications to transmons systems.

MA 12.6 Tue 10:45 H22

Optimal control of single flux quantum (SFQ) pulse sequences — •Per J. Liebermann and Frank K. Wilhelm — Universität des Saarlandes, Saarbrücken

Single flux quantum (SFQ) pulses are a natural candidate for on-chip control of superconducting qubits [1]. High accuracy quantum gates are accessible with quantum optimal control methods. We apply trains of SFQ pulses to operate single qubit gates, under the constraint of fixed amplitude and duration of each pulse. Timing of the control pulses is optimized using genetic algorithms and simulated annealing, decreasing the average fidelity error by several orders of magnitude. Furthermore we are able to reduce the gate time to the quantum speed limit. Leakage out of the qubit subspace as well as timing errors of the pulses are considered, exploring the robustness of our optimized sequence. This takes us one step further to a scalable quantum processor.

[1] R. McDermott, M.G. Vavilov, Phys. Rev. Appl. **2**, 014007 (2014)

MA 12.7 Tue 11:00 H22

Nonlinearities in Josephson-Photonics — •Björn Kubala and Joachim Ankerhold — Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany

Embedding a voltage-biased Josephson junction within a high-Q superconducting microwave cavity provides a new way to explore the interplay of the tunneling transfer of charges and the emission and absorption of light. While for weak driving the system can be reduced to simple cases, such as a (damped) harmonic or parametric oscillator, the inherent nonlinearity of the Josephson junction allows to access regimes of strongly non-linear quantum dynamics.

Classically, dynamical phenomena such as thresholds for higher-order resonances, other bifurcations, and up- and down-conversion have been found [1]. Here, we will investigate how and to which extent these features appear in the deep quantum regime, where charge quantization effects are crucial. Theory allows to employ phase-space quantities, such as the Wigner-density of the cavity mode(s) [2], but also observables amenable to more immediate experimental access, such as correlations in light emission and charge transport, to probe these novel non-equilibrium transitions.

[1] S. Meister, M. Mecklenburg, V. Gramich, J. T. Stockburger, J. Ankerhold, B. Kubala, PRB **92**, 174532 (2015).
[2] A. D. Armour, B. Kubala, J. Ankerhold, PRB **91**, 184508 (2015).

15 min. break

MA 12.8 Tue 11:30 H22

Normal-metal quasiparticle traps for superconducting qubits — •Amin Hosseinkhani — Peter Grunberg Institute (PGI-2), Forschungszentrum Julich, D-52425 Julich, Germany — JARA-Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

Superconducting qubits are promising candidates to implement quantum computation, and have been a subject of intensive research in the past decade. Excitations of a superconductor, known as quasiparticles, can reduce the qubit performance by causing relaxation; the relaxation rate is proportional to the density of quasiparticles tunneling through Josephson junction. Here, we consider engineering quasiparticle traps by covering parts of a superconducting device with normal-metal islands. We utilize a phenomenological quasiparticle diffusion model to study both the decay rate of excess quasiparticles and the steady-state profile of the quasiparticle density in the device. We apply the model to various realistic configurations to explore the role of geometry and location of the traps.

MA 12.9 Tue 11:45 H22

Decoherence and Decay of Two-level Systems due to Non-equilibrium Quasiparticles — •Sebastian Zanker, Michael Marthaler, and Gerd Schön — Karlsruher Institut für Technologie, Institut für Theoretische Festkörperpgysik, Karlsruhe, Deutschland

It is frequently observed that even at very low temperatures the number of quasiparticles in superconducting materials is higher than predicted by standard BCS-theory. These quasiparticles can interact with two-level systems, such as superconducting qubits or two-level systems (TLS) in the amorphous oxide layer of a Josephson junction. This interaction leads to decay and decoherence of the TLS, with specific results, such as the time dependence, depending on the distribution of quasiparticles and the form of the interaction. We study the resulting decay laws for different experimentally relevant protocols.

MA 12.10 Tue 12:00 H22

Theory of the double Quantum-dot Maser — •Clemens Müller and Thomas M. Stace — ARC Centre of Excellence for Engineered Quantum Systems, The University of Queensland, Brisbane, Australia

We consider a voltage-biased double quantum-dot (DQD) in the transport regime, dipole-coupled to a superconducting microwave cavity [1, 2]. We explore the effect of dissipative coupling of the DQD to a phononic environment and its influence on microwave gain and loss observed in the resonator. To this end, we develop a rate equation based on fourth-order perturbation theory in the dissipative and coherent DQD interactions. We compare our findings with the recent paper Ref.[3], where a different technique based on the Polaron transformation was used.

[1] Y.-Y. Liu, K. D. Petersson, J. Stehlik, J. M. Taylor, and J. R. Petta, PRL **113**, 036801 (2014)
[2] Y.-Y. Liu, J. Stehlik, C. Eichler, M. J. Gullans, J. M. Taylor, J. R. Petta, Science **347**, 285 (2015)
[3] M. J. Gullans, Y.-Y. Liu, J. Stehlik, J. R. Petta, J. M. Taylor, PRL **114**, 196802 (2015)

MA 12.11 Tue 12:15 H22

Upper bound for SL-invariant entanglement measures for mixed states of arbitrary rank — •Andreas Osterloh — Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany.

I present an algorithm that calculates an SL-invariant entanglement measure E as the threetangle of a mixed state of arbitrary rank. It is an alternative algorithm to ref. [1] and exploits the knowledge obtained for the rank-two case [2,3]. Whereas the known algorithm has an advantage of taking into consideration the whole range of the density matrix ρ, it on the other hand has the disadvantage of searching in a high-dimensional Hilbert space. Here, I only consider ensembles of two states each time but then calculate the upper bound obtained by the method presented in [2,3]. I discuss examples where the advantage of the new algorithm is obvious, but also highlight the obvious disadvantage of only considering rank two parts of ρ.

[1] S. Rodriques, N. Datta, and P. Love, PRA **90**, 012340 (2014)
[2] R. Lohmayer, A. Osterloh, J. Siewert, and A. Uhlmann, PRL **97**, 260502 (2006)
[3] A. Osterloh, J. Siewert, and A. Uhlmann, PRA **77**, 032310 (2008).

MA 12.12 Tue 12:30 H22

Occupation number entanglement in mesoscopic conductors — •David Dasenbrook[1] and Christian Flindt[2] — [1]Université de Genève, Genève, Switzerland — [2]Aalto University, Finland

The controlled entanglement of electrons in mesoscopic conductors has been theoretically investigated before using the spin- and orbital degrees of freedom. By contrast, entanglement of two spatially separated electronic channels using the fermionic occupation number has mostly been considered inaccessible due to the charge superselection rule. However, using non-local measurements or combining several copies of occupation number entangled states, the superselection rules can be lifted and the entanglement can be detected using current and noise measurements. We present the theory for an interferometric setup to detect entanglement in the electron-hole degree of freedom of electronic excitations[1] as well as a mesoscopic setup that demonstrates entanglement and nonlocality of a single electron[2].

[1] D. Dasenbrook and C. Flindt, PRB **92**, 161412(R) (2015)
[2] D. Dasenbrook, J. Bowles, J. Bohr Brask, P. P. Hofer, C. Flindt, and N. Brunner, arXiv:1511.04450 (2015)

MA 13: Magnetic Materials II

Time: Tuesday 9:30–11:15 Location: H31

MA 13.1 Tue 9:30 H31

Phonons and the metamagnetic transition in FeRh — •Michael Wolloch[1], Florian Hofer[2], Dieter Süss[2], and Peter Mohn[1] — [1]Institute of Applied Physics, Vienna University of Technology, Wiedner Hauptstraße 8-10, A-1040 Vienna, Austria — [2]Institute of Solid State Physics, Vienna University of Technology, Wiedner Hauptstraße 8-10, A-1040 Vienna, Austria

The meta-magnetic transition, from G-type antiferromagnetic (AFM) to ferromagnetic (FM) order at $\sim$ 350K, makes FeRh a very interesting material which could be used, for example, in a layered system in conjunction with FePt for heat assisted magnetic recording media [1,2,3]. Several explanations for the transition have been proposed, but there is still debate over the correct mechanism [4,5,6].

We present DFT calculations using the VASP code of several magnetic configurations of FeRh, including zero point energies and phonons. We find that FeRh is extremely sensitive to the choice of computational parameters and sensible to slight distortions in the lattice. Additionally we conclude that the vibrational zero-point energy is not negligible when considering the energetic hierarchy of different magnetic configurations.

[1] G. Shirane et al., *Phys. Rev.*, **134**, A1547 (1964)
[2] J.-U. Thiele et al., *Appl. Phys. Lett.*, **82**, 2859 (2003)
[3] D. Süss et al., *Appl. Phys. Lett.*, **89**, 113105 (2006)
[4] M. E. Gruner et al., *Phys. Rev. B*, **67**, 064415 (2003)
[5] R. Y. Gu et al., *Phys. Rev. B*, **72**, 012403 (2005)
[6] J. Kudrnovský et al., *Phys. Rev. B*, **91**, 014435 (2015)

MA 13.2 Tue 9:45 H31

Magnetic phase diagram of HoCu — •Wolfgang Simeth[1], Marein Rahn[2], Michael Wagner[1], Nives Bonacic[1], Anatoliy Senyshyn[3], Martin Meven[3], Sebastian Mühlbauer[3], Andre Heinemann[3], Tobias Weber[3], Tobias Schrader[3], Andreas Bauer[1], Robert Georgii[3] und Christian Pfleiderer[1] — [1]Technische Universität München — [2]Oxford University — [3]Heinz Maier-Leibnitz (FRM II)

The rare-earth system HoCu orders in the centrosymmetric CsCl-structure. As a consequence of several competing interactions (CEF as well as itinerant, indirect, and quadrupolar exchange interactions), the localised 4f magnetic moments of the Ho-atoms order in complex multiaxial arrangements [1]. We report the magnetic field dependence of the magnetic order up to 14 T as inferred from neutron diffraction and selected bulk properties (magnetization, ac susceptibility, and electrical transport).

[1] P. Morin and D. Schmitt, J. Magn. Magn. Mater. 21, 243 (1980)

MA 13.3 Tue 10:00 H31

Magnetic small-angle neutron scattering on bulk metallic glasses — •Denis Mettus[1], Andreas Michels[1], Dirk Honecker[2], Rainer Birringer[3], Michael Deckarm[3], and Andreas Leibner[3] — [1]University of Luxembourg, Luxembourg — [2]Institut Laue-Langevin, Grenoble, France — [3]Universität des Saarlandes, Saarbrücken, Germany

Bulk metallic glasses (BMG) are amorphous solids which are very well known for their excellent mechanical properties. In this contribution, we focus on their magnetic behavior and we discuss the influence of mechanical deformation on the magnetic microstructure as seen by magnetic-field-dependent small-angle neutron scattering (SANS). This technique allows one to investigate the spin distribution in the bulk of the material and on the nanometer length scale. We present and compare the results of unpolarized SANS on various BMG samples (as-cast, aged, deformed) and we analyze the SANS cross section in real space by computing the correlation function.

MA 13.4 Tue 10:15 H31

Strongly correlated alloys and dynamical mean field theory — •Alexander Poteryaev — M.N. Miheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Ekaterinburg 620137, Russia — Institute of Quantum Materials Science, Ekaterinburg 620075, Russia

For the physical description of the transition metal alloys both strong interactions and disorder have to be accounted for, and hence it is highly desirable to have a method that can treat, on equal footing, disorder and partially filled strongly interacting d states of transition metals. Combination of two techniques, the coherent potential approximation for disorder and the dynamical mean-field theory for correlated electrons which share an effective medium interpretation of the system of interest, allows one to investigate different physical properties of real alloys. The magnetic properties of Fe-Ni alloy and structural phase transition in Fe-Mn alloy are investigated as a function of temperature and concentration. Comparison of the coherent potential approximation and dynamical mean-field theory calculations agrees well with experimental data.

MA 13.5 Tue 10:30 H31

Determining the Verdet constant in antiferromagnetic materials — •Christian Tzschaschel[1], Stefan Günther[1], Takuya Satoh[2], and Manfred Fiebig[1] — [1]ETH Zürich, Switzerland — [2]Kyushu University, Japan

Recently, in the context of all-optical switching and ultrafast magnon generation, the Faraday effect and its inverse were discussed as possible mechanisms allowing to probe and stimulate magnetic excitations. The strength of both processes is related to the Verdet constant - a material parameter describing light-matter interactions in magnetic fields.

By measuring the spectral dependence of the Faraday rotation under the application of magnetic fields up to 6 T at temperatures down to 4 K, we are able to investigate fully compensated antiferromagnets like NiO and determine the Verdet constant in a broad spectral range covering the visible and near infrared. Subsequently, we compare the results to Bismuth-doped Yttrium-Iron-garnet as a well-known example of a material exhibiting a finite spontaneous magnetization.

Our results can be used to maximize the magnon generation efficiency with circularly polarized light via the inverse Faraday effect and at the same time optimize the sensitivity for the detection of magnetic excitations.

MA 13.6 Tue 10:45 H31

Flexible arrays of printed giant magnetoresistive devices — •Alexander Kutscher, Daniil Karnaushenko, Dmitriy Karnaushenko, Denys Makarov, and Oliver Schmidt — IIN, IFW Dresden, Helmholtzstraße 20, Dresden, 01069 Germany

Lightweight, flexibility and imperceptibility of magnetoelectronics is dictated by the design of modern portable and wearable devices[1]. Diverse printing and thin-film technologies were applied to satisfy the needs of this novel shape of electronics to achieve large-scale and cheap fabrication[2] capabilities. Recently, was developed printable magnetosensorics[3] relying on the giant magnetoresistive effect(GMR), which has already entered the field of flexible electronics[4]. Fast, high yield and homogenous printing of the magnetic sensors have to be achieved for industrial and commercial applications. Arrays of printed GMR sensors were fabricated on thin polymeric foils using a commercial dispenser robot. The GMR ink is applied in a form of dots on top of foil over the printed silver electrodes by the dispense printing. Hundreds of sensors could be produced. Various parameters like paste composition, binder, toxicity, viscosity and the dispensing process were optimised to obtain safe and reliable fabrication process. The printed sensor arrays possess up to 25% ratio with a high yield(>90%) across the array, broad operating temperature range and resistivity in the range of hundreds of Ohms, which is sufficient even for the most demanding applications. [1]M. Melzer, et al., Nat. Commun. 6(2015) 1 [2]H. Kang, et al., Sci. Rep. 4(2014) 5387[3]D. Karnaushenko, et al., Adv. Mater. 24(2012) 4518[4]D. Karnaushenko, et al., Adv. Mater. 27(2015) 880

MA 13.7 Tue 11:00 H31

Flux transfer across domain walls in the patterned Permalloy thin films — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P O. Box 151150, D-66041, Saarbrücken, Germany

Magnetic domain walls are subjects of intense fundamental research on controlling, manipulating and moving their internal configuration [1]. We have investigated the mechanism of magnetic flux transfer across domain walls in patterned Permalloy thin films under static magnetic field induced magnetization reversals. High-resolution images of cross-tie domain walls and asymmetric domain walls [2] were obtained by magnetic force microscopy for 40 nm and 130 nm thick Permalloy structures, respectively. The transformations between different internal structures of domain walls were studied by applying in-plane magnetic fields. The motion of the vortices, antivortices and line singularities [2] was tracked along the domain walls in order to understand the magnetization reversal of domain walls. The experimental results were compared to three-dimensional micromagnetic simulations to link these internal transformations to wall energies.

[1] J.Y. Lee et al., Phys. Rev. B 76, 184408 (2007) [2] A. Hubert, and R. Schafer, Magnetic Domains (Springer Verlag, Berlin, 1998)

MA 14: Focus: Magnetism as seen by neutrons

Organized by A. Schneidewind, S. Mühlbauer, and R. Georgii (Maier Leibnitz Zentrum, Garching)

Neutron scattering can serve as an essential tool for researchers studying magnetism offering a mostly exclusive access to a broad variety of static and dynamic correlations. It can be used to investigate magnetic structures, to determine magnetic interactions, to refine phase diagrams or to find dynamical timescales. In the suggested focused session examples from cutting edge research performed with the help of neutrons will be presented. We illustrate the diversity of magnetic phenomena -from magnetic spin ice and monopoles to heterostructures and interfaces- successfully understood by the use of neutron scattering and highlight its potential to a broader magnetism community.

Time: Tuesday 9:30–12:15 Location: H32

Invited Talk MA 14.1 Tue 9:30 H32

Breakthrough neutron spectroscopy for quantum magnetism — •Andrey Zheludev — Laboratory for Solid State Physics, ETH Zurich, Switzerland

Quantum magnetism is an area of research where neutron scattering has always played a leading role. Neutrons directly probe the very spin correlation functions that theorists are aiming to calculate. For quantum magnets, this comparison between theory and experiment can be very detailed and quantitative. Neutrons are also a great tool for studying quantum critical phenomena in magnets, just as they were irreplaceable in the study of thermodynamic magnetic phase transitions. Recently, the topic of quantum magnetism seemed to have lost its former luster. Many systems appeared to have been “perfectly well” understood, while for the remaining unexplored models there seemed to be few material prototypes. Fortunately, these concerns are being voided by previously unimaginable breakthroughs in neutron spectroscopy instrumentation, particularly at pulsed neutron facilities. Energy resolutions of 10 μeV are now routinely used to study spin excitations in very small samples and in very difficult sample environments with unprecedented statistics and signal to noise ratios. The enormous gains in data rates now permit us to study excitation spectra in their entirety, rather than focusing on just a few sharp and intense features. Totally new physics is being uncovered in many quantum magnets that were studied and declared “understood” 15 years ago. Theorists are again barely able to keep up with neutron experiments.

In my talk I shall illustrate these points with a few recent example.

Invited Talk MA 14.2 Tue 10:00 H32
Topological magnetism as seen by neutrons — •Roderich Moessner — MPI-PKS, Dresden, Germany

Neutron scattering has for a long time been the method of choice for understanding magnetic states of matter. The advent of topological states of matter – such as classical or quantum spin liquids – is posing a new challenge as these lack signatures such as Bragg peaks or spin waves. Here, we present the important role that neutrons can play in probing such new forms of magnetism, in particular their concomitant emergent gauge fields and fractionalised excitations such as spinons, monopoles or Majorana Fermions.

15 min. break

Invited Talk MA 14.3 Tue 10:45 H32
Magnetism at heterostructures and interfaces — Jochen Mannhart and •Hans Boschker — Max Planck Institute for Solid State Research, Heisenbergstrasse 1. 70569 Stuttgart, Germany

Two oxide magnetic heterostructures will be discussed. First is the interface of La0.67Sr0.33MnO3 (LSMO) and SrTiO3 (STO). Using magnetic depth profiling with polarized neutron reflectometry, we show that convential LSMO-STO interfaces have a magnetic dead layer. In contrast, interface engineered LSMO-STO interfaces, where the polar discontinuity has been removed by locally adjusting the LSMO composition, do no have a dead layer. As magnetic devices depend on the magnetization at the interface, the interface engineered heterostructures should improve device performance. The second material is atomically thin SrRuO3. Atomically thin ferromagnetic and conducting electron systems are highly desired for spintronics because they can be controlled with both magnetic and electric fields. We present (SrRuO3)1-(SrTiO3)5 superlattices of exceptional quality. In these superlattices the electron system comprises only a single RuO2 plane. We observe conductivity down to 50 mK and a ferromagnetic state with a Curie temperature of at least 30 K and signals of magnetism in magnetotransport persisting up to approximately 100 K.

Invited Talk MA 14.4 Tue 11:15 H32
Vortex matter: from superconductivity to skyrmions — •Sebastian Mühlbauer — Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Technische Universität München

Both superconducting vortex [1,2] and skyrmion lattices in chiral magnets [3] can be regarded as macroscopic lattices, formed by topological entities. Analogous to condensed matter, a large variety of phases is also observed for vortex and Skyrmion matter, resembling the particle like character and reflecting the underlying physical properties. Moreover, both vortex and Skyrmion matter represent ideal model systems for questions of general importance as topological stability and decay.

As for superconducting vortex matter, Skyrmion melting transitions, Skyrmion liquids and Skyrmion glass phases are expected to exist in various materials. Due to their topology, they provide an excellent showcase for the investigation of topological phase conversion [4].

Neutron scattering provides an ideal tool for the investigation of both vortex and Skyrmion matter. We present an overview how to address the static and dynamic properties of superconducting vortex and Skyrmion matter by means of neutron grating interferometry (nGI), time-resolved small angle neutron scattering (TISANE) and neutron resonance spin echo spectroscopy (NRSE). Our study paves the way how to access vortex and Skyrmion lattice melting as well as their current induced motion and dynamic properties in bulk samples.

[1] S. Mühlbauer et al., Phys. Rev. Lett 102 136408 (2009) [2] S. Mühlbauer et al., Phys. Rev. B 83, 184502 (2011) [3] S. Mühlbauer et al., Science 323 915 (2009) [4] P. Milde et al., Science 340, 6136, (2013)

Invited Talk MA 14.5 Tue 11:45 H32
Neutron spectroscopy – Collective excitations in (un)conventional superconductors — •Jitae Park — TU München at MLZ, Lichtenbergstr. 1, 85748 Garching

Superconductivity is one of the most fascinating phenomena in condensed matter because its macroscopic behavior is apparently originated from the quantum mechanics of electrons: Formation of electron pairs that are bound together via a small attractive interaction between them, also called Cooper pairs. Over several decades, dedicated theoretical works have revealed that collective motions of either atoms or spins are the most important ingredient for the electron pairing in the superconducting state. Owing to the uniqueness of a neutron scattering method with accessibility over wide momentum and energy space, we can preciesly measure such collective excitations in superconducting materials. In this talk, I will introduce how the inelastic neutron scattering study contributes to the superconductivity research field by presenting a few recent example cases mostly done at the research reactor in Munich.

MA 15: Magnetic Thin Films II

Time: Tuesday 9:30–12:00 Location: H33

MA 15.1 Tue 9:30 H33
Compositional tuning of boundary magnetization properties in epitaxial $Cr_{2-x}Al_xO_3$ (0001) films — •Lorenzo Fallarino[1], Christian Binek[2], and Andreas Berger[1] — [1]CIC nanoGUNE, Donostia - San Sebastian, Spain — [2]University of Nebraska, Lincoln, Nebraska, USA

The magnetoelectric antiferromagnet Cr_2O_3 (Chromia) is known to exhibit an equilibrium net magnetization at its (0001) surface [1]. This boundary magnetization (BM) can be exploited to switch the associated bulk antiferromagnetic order parameter solely by magnetic means in (0001) oriented thin Chromia films [2,3]. In order to investigate whether these BM properties can be extended to alloys containing different oxide materials, we investigated the effect of Al_2O_3 doping onto the structural and magnetic properties of Cr_2O_3. We fabricated a sample series of 100 nm thick epitaxial $Cr_{2-x}Al_xO_3$ (0001) films in the concentration range x = 0 - 0.6. Using SQUID magnetometry, we demonstrated that the critical temperature T_N of such alloy films can be tuned by using the BM as a probe to study the magnetic transition. Moreover, we evaluated the critical exponent and the absolute BM values for all the samples, which both corroborate the BM nature of the observed magnetic signals [4].

[1] K. D. Belashchenko, Phys. Rev. Lett. **105**, 147204 (2010);
[2] L. Fallarino et al., Appl. Phys. Lett. **104**, 022403 (2014);
[3] L. Fallarino et al., Phys. Rev. B **91**, 054414 (2015);
[4] L. Fallarino et al., Phys. Rev. B **91**, 214403 (2015);

MA 15.2 Tue 9:45 H33
The influence of low-energy proton irradiation on the magnetic properties of undoped TiO_2 anatase thin films — •Markus Stiller[1], José Barzola-Quiquia[1], Pablo Esquinazi[1], Daniel Spemann[2], Jan Meijer[2], Michael Lorenz[3], and Marius Grundmann[3] — [1]Abteilung für Supraleitung und Magnetismus, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany — [2]Abteilung Nukleare Festkörperphysik, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany — [3]Abteilung Halbleiterphysik, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany

The temperature and field dependence of the magnetization of epitaxial, undoped TiO_2 anatase thin films on sapphire substrates was investigated. Field hysteresis as well as zero-field cooled and field cooled curves were measured for the as-prepared thin films as well as after irradiation of low-energy protons. The anatase thin films exhibit ferromagnetism after proton irradiation, which strength does not increase linearly with the amount of irradiated protons. A clear magnetic anisotropy, opposite to the expected one, was observed after the first irradiation. The presence of impurities (with ppm resolution) was investigated by means of particle-induced X-ray emission. The experimental results indicate that Ti vacancies are the origin for the observed magnetic order.

MA 15.3 Tue 10:00 H33
Magnetic properties of YCo_5 epitaxial thin films. — •Shalini Sharma, Erwin Hildebrandt, and Lambert Alff — Institute of

Materials Science, Technische Universität Darmstadt, Germany

Rare earth-cobalt (R-Co) intermetallic compounds are of high interest for application as high-temperature permanent magnets. YCo_5 is predicted to exhibit high anisotropy at and above room temperature with a large magnetocrystalline anisotropy constant, K_1, of about 10^7 erg/cm^3. In this work, molecular beam epitaxy was used to synthesize epitaxial thin films of YCo_5 on (0001)-oriented Al_2O_3 substrates. X-ray diffraction revealed the growth window for phase pure YCo_5 thin films. The magnetic properties of the films were investigated using a SQUID magnetometer. In phase pure thin films, the (so far) highest coercivity was measured to be 3 kOe, and the highest saturation magnetization was 472 emu/cc at 300 K. It is well known, that these values depend strongly on the exact stoichiometry of the sample. We expect that further optimization will come closer to the values reported for single crystals.

MA 15.4 Tue 10:15 H33

Ferromagnetic resonance study of equiatomic FeRh thin films
— •Anna Semisalova[1,2], Sven Stienen[1], Craig W. Barton[3], Roman Boettger[1], Rantej Bali[1], Thomas Thomson[3], Michael Farle[4], Jürgen Fassbender[1], 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]University of Manchester, School of Computer Science, Manchester, UK — [4]University of Duisburg-Essen, Faculty of Physics and Center for Nanointegration, Duisburg, Germany

Chemically ordered FeRh alloy with nearly equiatomic composition is antiferromagnetic at room temperature and exhibits a first-order phase transition to the ferromagnetic (FM) state at 370 K. Here, we present the study of FM resonance (FMR) in non-capped and Pt-capped magnetron sputtered 40 nm FeRh films on a MgO(100) substrate and analyse the influence of ion irradiation and chemical disordering on their magnetic properties. The temperature dependent FMR study between 200-500 K allowed us to observe the hysteretic temperature behavior, accompanied by a clear transformation of the FMR line, and explore the complex magnetic structure of films. We distinguished and characterized the contribution of anomalous FM interfacial layers induced by atomic intermixing and lattice strain. Finally, we have revealed the formation of a magnetic phase with an out-of-plane easy axis of magnetization caused by low-fluence irradiation with Ne^+ ions.

MA 15.5 Tue 10:30 H33

Exchange driven spin spiral in Rh/Fe/Ir(111)
— •Niklas Romming[1], Markus Hoffmann[2,3], Bertrand Dupé[2], André Kubetzka[1], Kirsten von Bergmann[1], Stefan Heinze[2], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, 20355 Hamburg, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098 Kiel, Germany — [3]PGI-1/IAS-1, FZ Jülich and JARA, D-52424 Jülich, Germany

Magnetism in ultra-thin films can substantially differ from commonly known magnetic configurations e.g. due to hybridization at the interface, stacking faults, and broken inversion symmetry [1]. Spin spiral and skyrmion states were found in mono- and double layers of 3*d* on 5*d* transition-metal surfaces due to the competition between various magnetic interactions [1]. It was recently shown that the magnetic interactions of Fe/Ir(111) can be altered with a non-magnetic adlayer of Pd, changing its magnetic state from a nanoskyrmion lattice with 1 nm period to a spin spiral with 6-7 nm period [2].

Here, we combine spin-polarised STM with first-principles calculations to investigate the influence of a Rh adlayer on Fe/Ir(111). We show that the magnetic ground state of Rh/Fe/Ir(111) is a spin spiral with a period of 1-2 nm, which is driven by the exchange interaction. Its propagation direction depends on the Rh stacking and can deviate from the high-symmetry directions.

[1] K. von Bergmann *et al.*, JPCM **26**, 394002 (2014)
[2] N. Romming *et al.*, Science **341**, 636 (2013); B. Dupé *et al.*, Nature Commun. **5**, 4030 (2014)

15 min. break

MA 15.6 Tue 11:00 H33

Electric field switching of individual magnetic skyrmions
— •Pin-Jui Hsu, Andre' Kubetzka, Aurore Finco, Niklas Romming, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

Using electric fields offers an energy-efficient route toward tailoring the magnetic properties of materials. In particular, the capability of switching magnetic states by employing electric fields provides a great potential to future magnetic information technology. In the present work, we report on the electric field switching of individual skyrmionic objects. A spin spiral ground state with a periodicity of about 3.8 nm has been identified for Fe triple-layers (Fe-TL) grown on Ir(111) by using spin-polarized scanning tunneling microscopy (SP-STM). Field dependent SP-STM measurements reveal a magnetic phase transition from a spin spiral to a skrymionic state and then to a saturated ferromagnetic state. According to SP-STM measurements with in-plane spin sensitivity on three different rotational domains, the skyrmionic objects exhibit a unique rotational sense suggesting a sizable Dzyaloshinskii-Moriya (DM) interaction from the Fe-Ir interface as the driving force for their stability. Local writing and deleting of single magnetic skyrmions, i.e., switching between skyrmionic and ferromagnetic states of Fe-TL, have been demonstrated with a pronounced bias-polarity dependence. Based on the observed linear dependence of the threshold voltage Ut on the tip-sample distance, the electric field has been found to play the decisive role for the switching mechanism.

MA 15.7 Tue 11:15 H33

Ion-beam-induced magnetic and structural phase transformation of fcc Fe thin films on different substrates
— •Jonas Gloss[1], Michal Horký[2,3], Michael Schmid[1], Michal Urbánek[2,3], and Peter Varga[1,3] — [1]Institute of Applied Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Institute of Physical Engineering, Brno University of Technology, 616 69 Brno, Czech Republic — [3]CEITEC BUT, Brno University of Technology, 616 00 Brno, Czech Republic

Ultrathin fcc Fe films on Cu(100) have been studied extensively in the past for their unique capability of magnetic (non-magnetic to ferromagnetic) and structural (fcc to bcc) transformation upon ion beam irradiation [1,2]. Replacing Fe by $Fe_{78}Ni_{22}$ allows for growing metastable films up to 25 nm [3]. To facilitate applications, in the current work we use Si(100) and $SrTiO_3$(100) substrates with a Cu buffer layer. Cu on both substrates grows epitaxially, although not layer-by-layer. On these substrates the as-grown 8-nm $Fe_{78}Ni_{22}$ films are non-magnetic and transformable. We also present magnetic nanostructures in these films written by a focused ion beam.

[1] W. Rupp, et al., Appl. Phys. Lett. **93**, 063102 (2008).
[2] S. Shah Zaman, et al. J. Appl. Phys. **110**, 024309 (2011).
[3] J. Gloss, et al., Appl. Phys. Lett. **103**, 262405 (2013).

MA 15.8 Tue 11:30 H33

Competition between complex magnetic states of Fe/Re(0001)
— •Alexandra Palacio Morales, Kirsten von Bergmann, André Kubetzka, and Roland Wiesendanger — Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

Scanning tunneling microscopy on Fe/Re(0001) recently revealed the growth of an epitaxial Fe monolayer (ML) [1] as well as the Fe ML spin texture [2]. A transition from pseudomorphic to reconstructed areas was found with increasing coverage. In the pseudomorphic regions, a frustrated antiferromagnetic triangular spin structure, called Néel state, was observed.

Here, we focus on the reconstructed areas of Fe on Re(0001). We found isolated and dense packed reconstruction lines together with a spin spiral having a period of 4 atomic lattice constants along the reconstruction lines. Moreover, the Néel state is observed in the vicinity of the spin spiral.

[1] S. Ouazi, et al., Surf. Sci. **630**, 280 (2014).
[2] S. Ouazi, et al., Phys. Rev. Lett. **112**, 076102 (2014).

MA 15.9 Tue 11:45 H33

Dzyaloshinskii-Moriya interaction and magnetic texture in thin Fe films deposited on transition-metal dichalcogenides
— •Daniel Schröder[1], Svitlana Polesya[1], Sergiy Mankovsky[1], Hubert Ebert[1], and Wolfgang Bensch[2] — [1]Dept. Chemie, Universität München, D-81377 München, Germany — [2]Institute of Inorganic Chemistry, Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The magnetic properties of Fe monolayers deposited on top of different types of transition-metal dichalcogenides (TMDC) have been investigated by means of first-principles DFT calculations. Changing the structure and the composition of the substrate results in a considerable variation of magnetic properties of the Fe overlayer, in particular - of the magnetocrystalline anisotropy and interatomic exchange interactions. The calculated Dzyaloshinskii-Moriya(DM) interaction parameters have been used for a subsequent investigation of the magnetic structure of Fe overlayers using Monte Carlo simulations. Rather strong DM interactions have been obtained for some of the systems under investigation, which can lead to the formation of skyrmionic structures varying with the strength of an applied external magnetic field.

MA 16: Magnetization and Demagnetization Dynamics I

Time: Tuesday 9:30–12:30 Location: H34

MA 16.1 Tue 9:30 H34

Three-dimensional Character of the Magnetization Dynamics in Magnetic Vortex Structures — •Matthias Noske[1], Hermann Stoll[1], Manfred Fähnle[1], Georg Dieterle[1], Johannes Förster[1], Markus Weigand[1], Ajay Gangwar[2], Georg Woltersdorf[3], Andrei Slavin[4], Christian H. Back[2], and Gisela Schütz[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [2]Department of Physics, University of Regensburg, Germany — [3]Department of Physics, Martin Luther University, Halle, Germany — [4]Department of Physics, Oakland University, Rochester, MI, United States

Three-dimensional linear spin-wave eigenmodes of a Permalloy disk having finite thickness are studied by micromagnetic simulations based on the Landau-Lifshitz-Gilbert equation. The eigenmodes found in these simulations are interpreted as linear superpositions (hybridizations) of 'approximate' three-dimensional eigenmodes, which are the fundamental gyromode G_0, the spin-wave modes and the higher-order gyromodes G_N (flexure modes), the thickness dependence of which is represented by perpendicular standing spin waves. This hybridization leads to new and surprising dependencies of the mode frequencies on the disk thickness. The three-dimensional character of the eigenmodes is essential to explain the recent experimental results on vortex-core reversal observed in relatively thick Permalloy disks.

MA 16.2 Tue 9:45 H34

Optically induced magnetization dynamics probed by Lorentz microscopy — •Marcel Möller[1], Tim Eggebrecht[2], Nara Rubiano da Silva[1], Jan Gregor Gatzmann[1], Theo Diekmann[1], Armin Feist[1], Ulrike Martens[3], Henning Ulrichs[2], Vladyslav Zbarsky[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

Combining Lorentz microscopy with in-situ optical excitation promises fascinating new insights into magnetization dynamics. Following two different approaches, first we present the generation of a dense vortex-antivortex network by a single intense femtosecond laser pulse in a thin continuous Fe/SN bilayer. The spatial distribution of the vortex-antivortex network exhibits glasslike properties, with well-defined short-range correlations. The formation of the defect network is explained with a Kibble-Zurek-type mechanism involving a rapid temperature quench from the paramagnetic to the ferromagnetic phase.

Secondly, we will report on the ultrafast Lorentz imaging of nanostructured magnetic thin films. Applying a electron-pump/laser-probe scheme using an ultrafast transmission electron microscope (UTEM) will yield access to temporally and spatially resolved magnetization dynamics.

MA 16.3 Tue 10:00 H34

Topological Spin Textures as Emitters for Multidimensional Spin Wave Modes — Volker Sluka[1], Markus Weigand[2], Attila Kakay[1], Katrin Schultheiss[1], Artur Erbe[1], Vasyl Tyberkevych[3], Andrei Slavin[3], Alina Deac[1], Jürgen Lindner[1], Jürgen Fassbender[1], •Jörg Raabe[4], and Sebastian Wintz[4,1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]Oakland University, Rochester, USA — [4]Paul Scherrer Institut, Villigen, Switzerland

The investigation of propagating spin waves is a key topic of magnetism research [1]. For the excitation of spin waves with short wavelengths, it was typically necessary to either use transducers with sizes on the order of the desired wavelengths (striplines or point-contacts) or to generate those spin waves parametrically by a double-frequency spatially uniform microwave signal [2]. Only recently, a novel mechanism for the local excitation of spin waves has been discovered, which overcomes the wavelength limit given by the minimum patterning size. This method utilizes the translation of natural topological defects, namely the gyration of spin vortex cores [3]. In the present contribution we will show that in a vortex pair system with uniaxial magnetic anisotropy, spin waves of even different symmetries and dimensionalities can be excited. [1] Madami M. et al., Nat. Nanotechnol. 6, 635, (2011). [2] Gurevich A. G. and Melkov G. A., Magnetic Oscillations and Waves, CRC New York, (1996). [3] Wintz S. et al., Joint Intermag/MMM Abstract AC-07, (2013).

MA 16.4 Tue 10:15 H34

Thermally Tunable Coupled Magnetic Vortex Oscillators — •Michael Vogel[1], Johannes Wild[1], Bernhard Zimmermann[1], Michael Müller[1], Claudia K.A. 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

Recently, the magnetization dynamics in neighboring magnetic vortex oscillators coupled via their stray fields came into focus of research [K. Yu. Guslienko, V. Novosad, Y. Otani, H. Shima, and K. Fukamichi, Phys. Rev. B 65, 024414 (2001)]. The system behaves like damped coupled harmonic oscillators. It has been shown that the dynamics of such systems is strongly influenced by the strength of the magnetostatic interaction given by the distance between the elements and the relative configuration of the core polarizations, i.e., the directions of the out-of-plane magnetization components [A. Vogel, A. Drews, T. Kamionka, M. Bolte, and G. Meier, Phys. Rev. Lett. 105, 037201 (2010)]. The control of the coupling in such an array of magnetic discs is essential to implement logic operations. Here we present a novel technique to control the interaction of two or more vortex oscillators by directly influencing their resonance frequencies harnessing their temperature dependency.

MA 16.5 Tue 10:30 H34

Imaging of Higher Order Gyromodes in Vortex Structures — •Johannes Förster[1], Georg Dieterle[1], Matthias Noske[1], Ajay Gangwar[2], Michael Vogel[2], Hermann Stoll[1], Markus Weigand[1], Iuliia Bykowa[1], Michael Bechtel[1], Christian H. Back[2], and Gisela Schütz[1] — [1]MPI für Intelligente Systeme, Stuttgart, Germany — [2]Universität Regensburg, Germany

Magnetic vortex structures appear as ground states of the magnetization in suitable micron-sized ferromagnetic discs. These structures show a broad range of dynamic phenomena. Most basic is the fundamental gyromode where the vortex core gyrates around its equilibrium position with eigenfrequencies of a few hundred MHz. Resonant excitation of this mode causes the vortex core polarity to switch [1].

Besides this fundamental gyromode, higher order gyromodes were predicted in the GHz frequency range by micromagnetic simulations [2,3] and their frequencies were measured by FMR [3]. However, no imaging of such higher order gyromodes have been reported so far.

We will show movies of the first order gyromode in cylindrical Permalloy discs obtained by time-resolved scanning transmission X-ray microscopy. By resonant excitation of this mode switching of the vortex core polarity was observed. In addition, we started imaging the z-dependence of the flexure mode using sensor layers in our samples, by taking advantage of the element specificity of the XMCD effect.

[1] B. Van Waeyenberge, Nature 444, 461 (2006) [2] F. Boust and N. Vukadinovic, PRB 70, 172408 (2004) [3] J. Ding et al., Sci. Rep. 4, 4796 (2014)

15 min. break

MA 16.6 Tue 11:00 H34

Influence of a thermal gradient on parametrically excited magnons in YIG-Pt bilayers — Thomas Langner[1], •Alexander

Serga[1], Akihiro Kirihara[2], Burkard Hillebrands[1], and Vitaliy Vasyuchka[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany, Kaiserslautern, Germany. — [2]Smart Energy Research Laboratories, NEC corporation, Tsukuba, Japan.

It has been reported that the Spin Seebeck Effect (SSE) might influence the magnetic damping due to a thermal spin transfer torque mechanism. In this work we investigate the influence of the SSE on the parallel parametric generation of magnons. A modification of the damping parameter due to the SSE would lead to a change in the threshold power. We present investigations on an yttrium iron garnet sample covered by a 5 nm thick platinum film clamped between two separately controlled Peltier elements. The threshold power for the generation of parametrically pumped magnons was measured with respect to the applied external magnetic field, first changing the temperature of the sample homogeneously and in a second step with applied temperature gradient perpendicular to the sample plane where a pronounced longitudinal SSE is present. Precise measurements of the threshold power behavior reveal that there is no measurable influence of the spin Seebeck effect on the parametric excitation threshold in a wide range of magnon wavenumbers, whereas a homogeneous temperature change largely influences this threshold power. Financial support by DFG within SPP 1538 "Spin Caloric Transport" is acknowledged.

MA 16.7 Tue 11:15 H34

Study of FM/Pt,Ta bilayers for spin pumping by ferromagnetic resonance spectroscopy — •Andrés Conca, Sascha Keller, Björn Heinz, Laura Mihalceanu, Evangelos Papaioannou, and Burkard Hillebrands — FB Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The generation of pure spin currents without accompanying charge currents is of large importance for spintronics and is called to play a critical role in the design of future spintronic devices. The creation and injection of a spin current into a non-magnetic (NM) material from a ferromagnetic (FM) one is commonly referred to as spin pumping. Metallic FM/Pt bilayers show a large increase in magnetic damping due to the presence of spin pumping, and large inverse spin Hall voltages (ISHE) are observed. Valuable information can be gained with FMR techniques without the disturbance of rectification effects present in ISHE measurements. Concretely the parameter $g^{\uparrow\downarrow}$ is accessible.

Here we report on a study of the influence of spin pumping on the FMR properties by using a model epitaxial metallic system of Fe(100)/Pt bilayers and discuss the possible origin of the different observed phenomena. Additional reference samples with no Pt have been also measured to estimate the properties in absence of spin pumping. Additionally, we present also data on CoFeB/Pt and CoFeB/Ta systems to compare the situation with polycrystalline systems.

Support by the Carl Zeiss Stiftung and by M-era.Net is acknowledged.

MA 16.8 Tue 11:30 H34

Control of the effective spin-wave damping in Heusler-Pt waveguides via the spin-transfer torque effect — •Thomas Meyer[1], Thomas Braecher[1,3], Philipp Pirro[1,4], Tobias Fischer[1], Alexander A. Serga[1], Hiroshi Naganuma[2], Koki Mukaiyama[2], Mikihiko Oogane[2], Yasuo Ando[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan — [3]curr. affiliation: Univ. Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, 17 rue des Martyrs, 38054 Grenoble, France — [4]curr. affiliation: Institut Jean Lamour, Université Lorraine, CNRS, 54506 Vandœuvre-lès-Nancy, France

We present the control of the effective spin-wave damping by the spin-transfer torque (STT) exerted by a pure spin current injected into Heusler compound microstructured waveguides. The here used Cobalt-based Heusler compound $Co_2Mn_{0.6}Fe_{0.4}Si$ (CMFS) already provides a comparably low Gilbert damping, thus, this material is very promising for the use in future spintronic devices. In this work, via the STT effect, a pure spin current, generated in a Pt layer via the spin-Hall effect, can exert a torque on the magnetization in the adjacent CMFS layer. The obtained results show a strong influence of an applied DC current on the spin-wave properties. Investigations using only thermally excited spin waves exhibit a strongly increased spin-wave intensity due to a decreased effective damping. This shows the feasibility of using the STT effect in Heusler compound microstructures for future applications.

MA 16.9 Tue 11:45 H34

Magnetization Dynamics in Nanostructured Ni80Fe20 Trilayers — •Tobias Schneider[1,2,3], Kilian Lenz[2], Jürgen Lindner[2], Bernd Scheumann[2], Jürgen Fassbender[2,4], and Ilya N. Krivorotov[1] — [1]Department of Physics and Astronomy, University of California, Irvine, California 92697, USA — [2]Helmholtz-Zentrum Dresden - Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, 01328 Dresden, Germany — [3]Institute for Physics of Solids, Technische Universität Dresden, Zellescher Weg 16, 01069 Dresden, Germany — [4]Institute of Physics, Technische Universität Chemnitz, 09107 Chemnitz, Germany

Spin wave spectra of structured layered systems are interesting for fundamental research since such systems provide great opportunities to investigate spin wave boundary conditions derived for a single nanowire. Therefore precise measurements of the spin wave spectra are necessary. Here, we present electrically detected ferromagnetic resonance measurements of the spin wave spectrum of a Ni80Fe20 trilayer nanowire. The trilayer nanowire with a width of 800 nm was produced by electron beam lithography. The measured spin wave spectra for the easy and hard axis are compared to micromagnetic simulations to understand the magnetization dynamics in detail. The spin wave modes in this system can be divided into acoustic and optical modes known from interlayer exchange coupled films. Funding by the DFG/NSF in the framework of the Materials World Network program is gratefully acknowledged. This work was also supported by the PROMOS program of the TU Dresden.

MA 16.10 Tue 12:00 H34

Standing spin waves excited by spatially non-uniform ultrafast spin transfer torque in Fe/Au/Fe/MgO(001) multilayer — Ilya Razdolski[1], Alexandr Alekhin[1], Nikita Ilin[1], Jan Meyburg[2], Detlef Diesing[2], Vladimir Roddatis[3], Uwe Bovensiepen[4], and •Alexey Melnikov[1] — [1]Fritz-Haber-Institut der MPG, Abt. Phys. Chemie — [2]Universität Duisburg-Essen, Institut für Phys. Chemie — [3]Universität Göttingen, Institut für Materialphysik — [4]Universität Duisburg-Essen, Fakultät für Physik

Ultrafast spin dynamics is the key for development of data storage and spintronics devices. Of particular interest is the generation of ultrashort spin current (SC) pulses and the study of their subsequent spin transfer torque (STT) action on a ferromagnet. We excite non-equilibrium spin-polarized hot carriers (HC) in a top Fe layer of a Fe/Au/Fe/MgO(001) structure by 14 fs-long 800 nm laser pulse. Traversing the Au layer, these HC form SC pulses which are detected by the second harmonic generation: we demonstrate about 300 fs-long SC pulses in Au. When the HC reach the second, 15 nm-thick Fe layer, its magnetization (if it is non-collinear to the HC spin) experiences a torque and starts moving out of the equilibrium. Thus excited picosecond precessional dynamics of the magnetization is monitored by the magneto-optical Kerr effect. We show that owing to a spatially non-uniform STT, on top of the uniform precession, several lowest standing spin wave modes can be excited. Spectral analysis of the excited modes allows for an estimation of the STT depth in Fe to below 2 nm. DFG (ME 3570/1, Sfb 616) and EU 7-th framework program (CRONOS) are acknowledged.

MA 16.11 Tue 12:15 H34

Magnetization dynamics and spin transport in magnetic-tunnel-junctions — •Jakob Walowski[1], Ulrike Martens[1], Christian Denker[1], Robin John[1], Alexander Böhnke[3], Günter Reiss[3], Vladyslav Zbarsky[1,2], and Markus Münzenberg[1] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität, Greifswald, Germany — [2]Fakultät für Physik, Georg-August Universität, Göttingen, Germany — [3]CSMD, Physics Department, Bielefeld University, Germany

We apply ultra short laser pulses to initiate magnetization dynamics and spin-transport in magnetic layers of tunnel-magneto resistance junctions (MTJs) with out-of-plane magnetic anisotropy (PMA). The systems consist of ferromagnetic electodes (FM) separated by an insulator layers FM/MgO/FM. Both processes are induced by the absorption of photons into the electron and spin system.

Probing the dynamics using both components of the time-resolved magneto-optical kerr-effect, the Kerr rotation and Kerr ellipticity, the samples can be probed at different depths[1]. We do the measurements on a wedge sample, where the thickness of the FM electrodes is varied within the range of perpendicular magnetic anisotropy. This enables the insight into the processes in the layers stemming from spin-flip scattering and from spin-polarized transport. Both, spin dynamics and spin transport depend on the properties of the magnetic electrodes and the tunnel barrier.

Financial funding by the DFG SPP 1538 SpinCaT is acknowledged.
[1] *PRB J. Wieczorek et al.*, 92, 174410(2015)

MA 17: Poster Session I

Magnetic Materials, Thin Films, Nano- und Mikrostruktured Materials, Magnetic Imaging and Measurement Techniques, Particles and Bio- and Molecular Magnetism, Magnetic Heuslers, Half-metals, Semi-conductors and Oxydes, Exchange bias and magnetic coupling phenomena.

Time: Tuesday 9:30–12:30 Location: Poster B1

MA 17.1 Tue 9:30 Poster B1

How to accomplish (quasi) in-situ neutron reflectivity measurements on ultrathin magnetic films — •Sabine Pütter, Amir Syed Mohd, Stefan Mattauch, Alexandros Koutsioubas, Harald Schneider, and Thomas Brückel — Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, Garching, Germany

The investigation of ultrathin films which are sensitive to ambient air at large scale instruments is a challenge as the capabilities for on-site growth UHV chambers to measure in-situ are often limited, mostly due to lacking space. A common solution is the use of protecting cap layers on top of the films. However they might change the physical properties of the sample.

Our solution is a handy mini UHV-chamber which is used for sample transfer and quasi in-situ measurements at the neutron reflectivity instrument MARIA of the Jülich Centre for Neutron Science at MLZ in Garching. The samples are prepared in the adjacent thin film laboratory by molecular beam epitaxy and moved into the compact chamber for transfer. It is equipped with sapphire windows, an SAES getter pump and a wobble stick, which serves also as a sample holder for samples of up to 1.4 cm^2. The pressure in the transfer chamber is kept below 10^{-9} mbar. Neutron reflectivity measurements can be performed at room temperature in magnetic fields of up to 600 mT.

We present first polarized neutron reflectivity measurements on Co thin films at room temperature in a magnetic field of 300 mT in the Q-range up to 0.2 $Å^{-1}$.

MA 17.2 Tue 9:30 Poster B1

VEKMAG - a new vector magnet beamline in BESSY II — •Chen Luo[1], Hanjo Ryll[2], Florin Radu[2], Steffen Rudorff[2], Olive Rader[2], Tino Noll[3], D. A. Tennant[4], Andrew James Britton[5], Lucas Arruda[5], Yin Ming Chang[5], Jorge Miguel[5], Wolfgang Kuch[5], Radu-Marius Abrudan[6], Hartmut Zabel[6], Georg Woltersdorf[7], Markus Hollnberger[1], and Christian Back[1] — [1]Universität Regensburg — [2]Helmholtz-Zentrum Berlin — [3]Technische Universität Berlin — [4]Oak Ridge National Laboratory, USA — [5]Freie Universität Berlin — [6]Ruhr-Universität Bochum — [7]Martin-Luther-Universität Halle-Wittenberg

VEKMAG is a vector superconducting magnet station, which is being jointly developed by Regensburg University, Free University Berlin, Ruhr University Bochum, and Helmholtz Zentrum Berlin. The instrument is installed at the PM2 dipole beamline of the synchrotron facility BESSY II.

The instrument is designed for XAS/XMCD/XMLD measurements, as well as for ferromagnetic resonance (FMR) and electron paramagnetic resonance (EPR) measurements using XMCD. Its 3D vector magnet can provide 9 T field in the x-ray beam direction, 2 T field anywhere in the horizontal plane, and 1 T field in all directions. It has two variable temperature inserts (VTI) - the low temperature VTI and the FMR VTI which allow measurements with a temperature range of 2 K-400 K and 4 K-500 K respectively.

The VEKMAG project is funded by the German Federal Ministry for Education and Research (BMBF).

MA 17.3 Tue 9:30 Poster B1

Resonant Soft X-Ray Diffraction on Chiral Multiferroic Ba3TaFe3Si2O14 — •Mahesh Ramakrishnan[1], Yoav William Windsor[1], Laurenz Rettig[1], Aurora Alberca[1], Elisabeth Bothschafter[1], Yves Joly[2], Rafik Ballou[2], Virginie Simonet[2], Pascal Lejay[2], Valerio Scagnoli[1], and Urs Staub[1] — [1]Swiss Light Source, Paul Scherrer Institut, Villigen PSI, Switzerland — [2]Institut Neel, CNRS and Universite Grenoble Alpes, Grenoble Cedex 9, France

We study the incommensurate spin structure of the multiferroic helical butterfly Ba3TaFe3Si2O14 using resonant soft x-ray diffraction. We investigate the role of the out-of-plane spin moments in the magnetically induced lattice modifications resulting in ferroelectric polarization. We also combine ab initio calculations and results from recent neutron scattering measurements to re-examine the symmetry of the low temperature crystal structure.

[1] Scagnoli V. et al., Phys. Rev. B 88 104417 (2013)
[2] Chaix L. et al., arXiv:1506.06491 (2015)

MA 17.4 Tue 9:30 Poster B1

Research and cost-saving production of size-selected magnetic nanoparticles from toners — •Miriam Leifels, Paula Weber, and Mathias Getzlaff — Heinrich-Heine-Universität Düsseldorf

The investigation of laser printer toners proves that they often contain magnetic nanoparticles. The aim is to isolate them from the nonmagnetic ones as a cost-saving method for production. There are many constructive characterization methods like energy dispersive x-ray spectroscopy, dynamic light scattering, x-ray diffraction, scanning electron microscopy and transmission electron microscopy to analyze particles which are part of toners. Thus, we obtain information about the element composition, size and shape of the particles. It shows that all the toners which contain magnetic particles have a bimodal size distribution. It is possible to isolate the magnetic particles from the nonmagnetic ones. For that process we solve the toner powder in a suitable solvent. Subsequently, we use a little magnet to isolate all the magnetic particles out of solution. This enables to make measurements only with the magnetic particles and independently only with the nonmagnetic ones, exemplarily by dynamic light scattering. After separation we are able to measure the size of the magnetic particles and nonmagnetic particles separately. It shows that the magnetic particles have a different size as the nonmagnetic particles. One peak of the bimodal size distribution only represents magnetic and the other peak only nonmagnetic particles.

MA 17.5 Tue 9:30 Poster B1

Magnetic and structural propertiesof small binary Fe_mGe_n, Ni_mGe_n clusters — •A. Ziane[1,2], A. Mokrani[3], M. Zemirli[2], and M. Benakki[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Laboratoire de Physique et Chimie Quantique, Université Mouloud Mammeri de Tizi-Ouzou, B.P. N^{o}17 RP, Algeria — [3]Institut des Matériaux Jean Rouxel, BP 32229, 2 rue de la Houssinière, F-44322 Nantes cedex, France

Transition metal germanides clusters could be considered as an ideal system for studying how the localized *d* electrons interact with the *sp* quasi-free electrons gas to enhance the transition metal (TM) magnetic moments, and then explain the unusual large moments observed when TM are adsorbed on *sp* metal surfaces [1]. Here we investigate from first-principles the magnetic and structural properties of small binary Fe_mGe_n, Ni_mGe_n clusters. We show that the clusters prefer the 3D closed structures with interatomic distances that are dependent on the clusters sizes. The binding energy increases with the cluster size and the addition of an atom, regardless of its nature, strengthens the stability of the system. Interestingly, the Germanium induced moments are negligible but couple antiferromagnetically to the TM moments. All of non magnetic Ni_mGe_n clusters have a low HOMO-LUMO gap in contrast to Fe_mGe_n clusters, which present a relatively large gap in only one spin channel revealing thereby their semi-metallic nature.

[1] Qun Jin *et al.*, The Journal of Chemical Physics **128**, 124319 (2008)

MA 17.6 Tue 9:30 Poster B1

Carbon nanotube encapsulated magnetic particles: Insights from statistical analysis — •Markus Gellesch[1], Marcel Haft[1], Silke Hampel[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]IFW Dresden, Institute for Solid State Research, PF 270116, 01171 Dresden, Germany — [2]Institute for Solid State Physics, Dresden Technical University, TU Dresden, 01062

We report investigations of assemblies of carbon nanotube encapsulated intermetallic magnetic nanoparticles. As a result from annealing treatments with various durations, the evolution of particle size and, likewise, of magnetic properties with progressing annealing duration could be observed. Here, we present a thorough statistical analysis of particle samples which yielded a multimodal size distribution. The investigation of this size distribution as function of annealing time provided the grounds to formulate a model for formation and growth of metallic particles inside confined geometries (here: the inner cavity of the carbon nanotubes). The derived average particle size well-described known magnetic behavior of ferromagnetic nanoparticles. In detail, a multi- to single domain transition, as well as indications for a transition to the superparamagnetic state, were found in coercivity data as function of the characteristic nanoscale length of the considered nanoparticulate systems. Our study emphasizes the advantage of a detailed statistical analysis of assemblies of magnetic nanoparticles in order to obtain insights on particle formation and growth and, subsequently, on related physical properties, such as magnetism.

MA 17.7 Tue 9:30 Poster B1

magnetic hardening effect in self-assembled iron oxide nanoparticle films — •Xiao Sun, Oleg Petracic, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52428 Jülich

By comparing the hysteresis loops of iron oxide nanoparticles (NPs) cooled at different magnetic fields, a hardening effect can be observed. The squareness and hardness of hysteresis loops is significantly enhanced with increasing the magnetic cooling field. Due to the antiferromagnetic (AF) wustite component, the spins of the ferrimagnetic 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. Self-assembled NP films have been fabricated using various methods (drop-casting, spin-coating, and liquid-air-interface) using 15 or 20nm iron oxide NPs. Large areas of self-assembled NPs has been achieved using the liquid-air interface method. The hardening effect of diluted iron oxide NPs is compared to self-assembled NP films.

MA 17.8 Tue 9:30 Poster B1

Magnetic force microcopy in the light of the pseudo-pole model — •Adrian Schillik[1], Matthias Stocker[1], Berndt Koslowski[1], Riedmüller Riedmüller[2], Runbang Shao[2], and Ulrich Herr[2] — [1]Institut für Festkörperphysik, Universität Ulm, D-89081 Ulm — [2]Institut für Mikro- und Nanomaterialien, Universität Ulm, D-89081 Ulm

Magnetic force microscopy (MFM) is a powerful and simple tool to analyze magnetic materials and structures down to the nano-meter scale. Though in use since almost 3 decades MFM suffers from a significant handicap: it is difficult to obtain quantitative results. This could be overcome by the recently proposed pseudo-pole model [1] assuming a cone which is covered homogeneously with dipoles pointing to the tip of the cones. The magnetic tip is then characterized by a single parameter and the field distribution is given by a simple analytic expression in the half-space in front of the tip. We tie in to the pseudo-pole model by verifying its general applicability and trying to uncover limitations. Here we report on the status of the resumed project. [1] Häberle, Thomas, et al. "Towards quantitative magnetic force microscopy: theory and experiment." New Journal of Physics 14.4 (2012): 043044.

MA 17.9 Tue 9:30 Poster B1

Exchange Bias in Granular Ferromagnet/Antiferromagnet Nanostructures — •Runbang Shao, Benjamin Riedmüller, Balati Kuerbanjiang, and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland

Exchange bias of ferromagnetic (FM) nanoparticles could be used to beat superparamagnetic limit, and the storage density of hard disk drive can be increased subsequently. For such application, a nanostructure with Ni nanoparticles embedded in an antiferromagnetic (AF) IrMn matrix is investigated. To determine the average size of the nanoparticles, the superparamagnetic m-H curve of Ni nanoparticles embedded in a diamagnetic matrix at room temperature is fitted using a superposition of Langevin functions. The fitted log-normal size distribution coincides with the result obtained by T-SEM analysis of unembedded Ni particles. After a field cooling procedure, exchange bias is observed for 10 nm Ni nanoparticles embedded in a IrMn matrix at 10 K. The exchange bias dependence on the Ni volume filling factor is studied. The exchange bias increases with the decreasing Ni volume filling factor up to a maximum of 650 Oe. By modeling the dependence of exchange bias on FM volume filling factor we conclude that a shell of AF material with a minimum thickness of 5.7 nm is needed around one Ni nanoparticle to achieve the largest exchange bias.

MA 17.10 Tue 9:30 Poster B1

Manipulation of Magnetic Nanoparticles for Lab-on-Chip systems — Shalini Easwardas, •Benjamin Riedmüller, Florian Ostermaier, and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Ulm, Deutschland

Magnetic nanoparticles are widely used for Lab-on-chip systems. In such applications, biological analytes can be specifically bound to the surface of the magnetic particles. Many of these applications require a highly accurate and controlled manipulation of the particles. A common principle for manipulation is the application of magnetic field gradients by which a force on the particles is generated. Here we show a manipulation technique based on the superposition of field gradients generated by tapered conductor lines and an additional homogeneous magnetic field. By this technique we are able to position single superparamagnetic particles in two dimensions on length scales > 100 um with a precision of < 1 um. Our results show that the short-term fluctuations of the particle as quantified by the mean square displacement (MSD) are strongly influenced by the particle-surface interaction. By analyzing the fluctuations on time scales of several minutes the trap stiffness can be extracted. Combining the experimentally observed trap stiffness with the values predicted from quantitatively modeling the force landscape around the energy minimum of the trap, the magnetic moment of a single superparamagntic particle can be extracted with high precision.

MA 17.11 Tue 9:30 Poster B1

Magnetic characterization of iron oxide superparamagnetic nanoparticles on surfaces — •Stanislav Emelianov, Maryam Youhannayee, and Mathias Getzlaff — Institute für angewandte physik, Heinrich-Heine-universität Düsseldorf

Nowadays Magneto-optic effects are widely used in magnetic research. Magnetic characteristics of thin films and nanoparticles properties are of big interest for scientists due to its wide application in different field such as medicine. In our experiment we investigate the properties of iron oxide superparamagnetic nanoparticles on surface applying SQUID and also the methodology and the setup 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. In our experiment superparamagnetic nanoparticles are prepared by wet chemical synthesis. It is a coprecipitation of Ferric Chloride and Ferrous Sulphate with Ammonium hydroxide. The obtained parameters are illustrated by means of hysteresis loops which indicate the relevant magnetic characteristics.

MA 17.12 Tue 9:30 Poster B1

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. However, the accuracy of detection in the original setup is limited by the resolution of the optical microscope. The combination of both methods opens up new perspectives for applications of nanoparticles in absorbing media. We present first experimental results obtained by integrating a magnetic micro-trap into an optical tweezer setup. It is demonstrated that under suitable conditions stable positioning of commercially available microbeads (Dynabeads MyOne Streptavidin T1, diameter 1 μm) in the optical tweezer can be achieved.

MA 17.13 Tue 9:30 Poster B1

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 — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Designing an analysis platform for microfluidic devices based on the directed transport of particles requires an estimate of the particle's behaviour in the presence of transversal liquid flow. The controllable movement of superparamagnetic particle rows above magnetically stripe-patterned exchange bias (EB) layer systems can be used to efficiently transport analyte molecules attached to the particle in a microfluidic structure.[1] The head-to-head and tail-to-tail orientation of the magnetization in adjacent stripe domains vertical to the long stripe axis is introduced to the EB sample by ion bombardment induced magnetic patterning (IBMP). Particle velocities perpendicular to the direction of their simultaneous transport caused by transversal fluid flows of defined rates have been experimentally determined. It has been shown that their velocities along the flow direction are 2 to 3 magnitudes smaller than the mean fluid velocity since the particles are transported close to the sample surface. The trajectory of a particle remains almost unaffected and allows for the purification of biomolecules in microfluidic devices with transversal flow components.

[1] D. Holzinger, I. Koch, S. Burgard, and A. Ehresmann, ACS Nano 9, 7323 (2015)

MA 17.14 Tue 9:30 Poster B1

Micro Hall-Magnetometry: Studying magnetic nanostructures using First Order Reversal Curves (FORC) — •Merlin Pohlit, Paul Eibisch, Fabrizio Porrati, Antonia Morherr, Michael Huth, and Jens Müller — Institute of Physics, Goethe-University, Frankfurt a. M., Germany

Micro Hall-Magnetometry is a sensitive technique that allows to study the local magnetic induction of macroscopic samples as well as to perform high-resolution measurements of individual or small arrays of magnetic micro- and nanoparticles. For the latter experiments, six adjacent Hall-crosses that are tailored by electron beam lithography to fit to the samples' dimensions provide continuous access to the magnetization via the stray field emanating from the particles during magnetization reversal. While particular techniques for studying magnetic interaction effects within macroscopic samples like First Order Reversal Curves (FORC) or Henkel plots are well-established, the same methods are only scarcely applied in the research field of interacting nanomagnets. Here, we first demonstrate a proof-of-concept experiment by studying a floppy disk sample, thereby reproducing literature results, and comparing FORC diagrams obtained by using a micron-sized Hall-sensor and data collected by a commercial vibrating sample magnetometer. Subsequently, FORC data are obtained for a single Cobalt nanomagnet and will be presented alongside FORC measurements of dipolar-coupled arrays of Co nanoislands, i.e. the building blocks of artificial square spin ice[1,2]. [1]Pohlit et al., J. Appl. Phys. 117, 17C746 (2015) [2]Pohlit et al., JMMM, 10.1016/j.jmmm.2015.08.072 (2015)

MA 17.15 Tue 9:30 Poster B1

Control of the Magnetic Structure of [Co/Pd] and TbFe Thin Films by Direct Laser Interference Patterning — •Philipp Graus[1], Martin Stärk[1], Frank Schlickeiser[1], Dennis Nissen[2], Birgitt Hebler[2], Elke Scheer[1], Paul Leiderer[1], Manfred Albrecht[2], Mikhail Fonin[1], and Johannes Boneberg[1] — [1]Universität Konstanz — [2]Universität Augsburg

Pulsed two beam direct laser interference patterning (DLIP) is used to generate two dimensional temperature patterns on a magnetic sample. In contrast to other methods like electron beam lithography, DLIP offers the possibility to pattern large areas on a timescale of a few nanoseconds in a one-step process. Usually DLIP is used to pattern surfaces, but here we focus on local periodic heating on the nanoscale. We investigate the effect of heat on thin magnetic Co/Pd multilayer systems and TbFe alloys which offer a strong perpendicular anisotropy. We compare results from experiments from 55 μm interference period down to 500 nm period. For both types of materials three different magnetic regions arise. These regions can be assigned to defined temperatures. In the case of Co/Pd the temperature gives rise to a intermixing process of the former separated multilayer system. For TbFe a phase transition from amorphous to polycrystalline takes place. These findings have been confirmed by numeric simulations using the Landau-Lifshitz-Bloch (LLB) formalism.

MA 17.16 Tue 9:30 Poster B1

Spin wave eigenmodes in transversely magnetized thin film ferromagnetic wires — •Sven Stienen[1], Jürgen Lindner[1], Zheng Duan[2], Ilya Krivorotov[2], Nathalie Reckers[3], and Rodrigo Arias[4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institue of Ion Beam Physics and Material Research, 01328 Dresden, Germany — [2]Department of Physics and Astronomy, University of California, Irvine 92697, USA — [3]Experimentalphysik - AG Farle, Fakultät für Physik and Center for Nanointegration, Universität Duisburg-Essen, 47048 Duisburg, Germany — [4]Departamento de Fisica, FCFM, Universidad de Chile, Santiago, Chile

Research in the field of spin transport received increasing attention within the last couple of years, due to the possibility to transmit information without current losses. To utilize spin transport in a defined way, it is necessary to create spin channels to guide spin currents. In this context we present a study of spatially confined spin wave eigenmodes in transversely magnetized thin permalloy wires with three different widths. The focus is put on the strongly localized edge modes, which are investigated by means of broadband ferromagnetic measurements that are compared to an analytic model and micromagnetic simulations. Our data shows that the measured results of the edge mode cannot be explained by just taken into account intrinsic dipolar pinning. Only by inducing an extrinsic edge pinning in the permalloy wires, we are able to give a quantitative description of the eigenfrequency and spatial profile as function of the wire width.

MA 17.17 Tue 9:30 Poster B1

Field working window of magnetic domain wall sensors — •Benjamin Borie[1,2], Johannes Paul[1], Mathias Kläui[2], and Hubert Grimm[1] — [1]Sensitec GmbH, 55131 Mainz, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

The potential of timeless data storage with very low power provides a certain advantage to magnetic domain wall based sensors [1] as technological solutions. Still the industry remain unable to offer reliable devices [2]. The stochasticity of the domain wall behaviour concerning its pinning and depinning events as well as the complexity of the manufacturing constitute the major issues for the technology to reach the market. Sensors probe a certain field window of work. The failure events such as an unwanted nucleation and a pinning of a domain wall have to be outside this window. The study reports the influence of roughness, crystallisation, shape and material stacks on the magnetic operating window of a free layer of a multi-turn sensor driven by rotating external field. The roughness and the crystallite sizes are likely to create a potential landscape that increase the pinning and reduces the nucleation field. NiFe, CoFe and CoFeB free layers can be fabricated and investigated using transport measurements such as the GMR effect currently used by the sensor and MOKE microscopy measurements to ascertain an understanding of the physics involved. [1] M. Diegel et. al., IEEE Trans. Magn. 45, 3792 (2009) [2] A. Bisig et al., Nat. Commun. 4, 2328 (2013).

MA 17.18 Tue 9:30 Poster B1

Minimization of redepositions during ion beam etching by using a dual angle etching technique — •Michael Schneider[1], Martin Kewenig[1], Tobias Fischer[1], Bert Lägel[2], Thomas Löber[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Nano Structuring Center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

The occurence of redeposition effects in the ion beam etching process is usually minimized by optimizing the etching angle. However, there are still non-negligible redepositions, such as the formation of raised edges on microstructures. We observed raised edges with heights of up to several tens of nanometers, which is even larger than the thickness of the structures.

Etching in two steps by different angles can provide a further reduction of these effects. We have fabricated waveguides of the ferromagnetic materials $Ni_{81}Fe_{19}$ and $Co_{40}Fe_{40}B_{20}$ by using a dual angle etching technique. As a result, we achieved a significant reduction of the raised edges on microstructures, which has been examined by Atomic Force Microscopy and Scattered Electron Microscopy measurements.

These findings pave the way for future applications in magnon spintronics, since the surface quality of magnetic waveguides has a noticeable influence on the propagation properties of spin waves in such microstructures.

MA 17.19 Tue 9:30 Poster B1

Magnetic interactions within Fe-Pt nanoparticles — •Svitlana Ponomarova[1], Valentyn Tatarenko[1], Oleksandr Ponomarov[2], Valerii Odnosum[1], and Yurii Koval[1] — [1]G.V. Kuyrdyumov Institute for Metal Physics, Kyiv 03680, Ukraine — [2]IntroPro LLC, Kyiv 02140, Ukraine

As well known, magnetic and other material properties are very sensitive to the size of their particles, to their organization when they are non-isolated, and to the chemical content and spatial order. The binary Fe-Pt alloys exhibit high magnetic anisotropy in their ordered L10 phase with high coercivity, good mechanical properties and excellent chemical stability. In present work, calculation of parameters of exchange interactions within the magnetic Fe-Pt nanoparticles for the platinum content range of L10-(super)structure existence (35-55 at.% Pt) have been estimated. The Heisenberg model for the system of randomly located spins, concerning 'slowly'-relaxing arrangement of their atomic carriers in a lattice was updated for binary solid solutions, which consist of two magnetic components (Fe and Pt). Strict dependence between the Curie temperature and the nanoparticles' size was taken into consideration in frame of the finite-size-scaling theory. Available experimental and theoretical values of magnetic moments showed that the most appropriate set of spin numbers is sFe=3/2 and sPt=1/2. Decreasing of magnitudes of exchange interaction parameters was obtained with rising of nanoparticles size. Temperature dependences of spontaneous magnetizations for Fe and Pt subsystems of nanoparticles with different sizes at fixed equiatomic composition are obtained.

MA 17.20 Tue 9:30 Poster B1

Tuning the magnetic behavior of regular arrays of magnetic nanoparticles by their shape — •Alexander Fabian[1], Matthias T. Elm[1], Dieter Ehlers[2], Hans-Albrecht Krug von Nidda[2], and Peter J. Klar[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen — [2]Institut für Physik, UniversitätAugsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Magnetite nanoparticles are a promising material for application in spintronic devices since magnetite possesses a very high spin polarization and a high Curie temperature. Reducing the size of the bulk material to the nanoscale may alter the magnetic properties e.g. nanoparticles will become superparamagnetic. Here, we present the characterization of the magnetic properties of regular arrays of magnetic nanoparticles with diameters of about 20 nm by FMR and SQUID measurements. Using a bottom-up process magnetic nanoparticles are arranged in regular arrays. Small openings with high lateral aspect ratios are defined in PMMA by e-beam lithography. Then the nanoparticles are self-assembled in the openings using the meniscus force deposition method. Angle dependent FMR measurements are performed. The resonance field shows a 180°-symmetry in both in-plane and out-of-plane configuration, which can be attributed to the elongated shape of the nanoparticle arrangements. SQUID measurements confirm a superparamagnetic behavior of the particles, but also exhibit differences in the magnetization in comparison to the typical superparamagnetic FC and ZFC curves of a circular thin film of nanoparticles.

MA 17.21 Tue 9:30 Poster B1

Application of He-ion microscopy for advanced light-ion induced magnetic patterning of exchange bias layer systems — •Alexander Gaul[1], Nicolas Müglich[1], Daniel Emmrich[2], André Beyer[2], Johanna Hackl[3], Hatice Doganay[3], Slavo Nemsak[3], Armin Gölzhäuser[2], and Arno Ehresmann[1] — [1]Department of Physics & CINSaT, University of Kassel — [2]Physics of Supramolecular Systems and Surfaces, University of Bielefeld — [3]PGI-6, FZ-Jülich

Light-ion bombardment induced magnetic patterning (IBMP) of exchange bias (EB) bilayer systems by Helium ions through a shadow mask is a well-known technique to locally tailor the magnetic anisotropy on the micrometer length scale. Here we demonstrate the use of Helium ion microscopy (HIM) for the fabrication of artificial magnetic domains in EB systems without shadow masks. In this way, magnetic domain patterns with lateral dimensions on nano meter scales become feasible. Therefore, designed magnetic domain patterns were written by a He ion beam of 10 nm diameter into the continuous EB layer. The influence of size, anisotropy and shape on the formation of magnetic domains and domain walls within one sample has been analyzed by magnetic force microscopy (MFM) to detect the domain wall charge distribution, by x-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM) to get detailed information about the magnetization orientation within the domains, and domain walls and by Kerrmicroscopy to study the remagnetization behavior in different regions of the domains with spatial resolution.

MA 17.22 Tue 9:30 Poster B1

Tuning of aspect ratio and magnetic material parameters for pronounced flux closure in giant magnetoimpedance (GMI) sensors — •Gregor Büttel, Julian Joppich, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, D66041, Saarbrücken, Germany

It is well known that sputter-deposited Permalloy (Py) shows a strong perpendicular anisotropy above a critical thickness destroying its soft magnetic properties needed for GMI-based magnetic field sensors. Therefore many groups use a multilayer system with a non-magnetic spacer to prevent the appearance of stripe domains and a wide hysteresis curve. We have studied the magnetic properties and microstructure of such micrometer-sized structures sputtered from targets of slightly different Ni:Fe ratio while analyzing target and sample composition by EDX. Different spacer materials are investigated for their influence on strong flux closure of the magnetic layers by MOKE microscopy and MFM. We find that the target ratio strongly determines the critical thickness and at a Ni:Fe ratio of around 79:21 a film can be deposited up to 1000 nm showing neither stripe domains nor columnar microstructure. This is interesting for GMI thin film sensors, as multilayer systems show a weaker flux closure and complicated domain structures compared to Py/spacer/Py layer systems in our micromagnetic simulations and measurements.

MA 17.23 Tue 9:30 Poster B1

Fabrication and lift-off of magnetic 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]Department 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 Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

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. The particles were geometrically characterized by scanning electron microscopy. Magnetically they were characterized 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.

[1] V. R. Kolli, C. Woidt and H. Hillmer, Advanced Materials Research. Vol. 1119, pp. 179-183 (2015) Trans Tech Publications

MA 17.24 Tue 9:30 Poster B1

Evolution of magnetic domains in ion-induced single nanostructures — •Anna Semisalova[1], Sebastian Wintz[1,2], Gregor Hlawacek[1], Ciarán Fowley[1], Kay Potzger[1], Jürgen Lindner[1], Jürgen Fassbender[1,3], and Rantej Bali[1] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]Paul Scherrer Institute, Villigen-PSI, Switzerland — [3]TU Dresden, Germany

Ion-induced chemical disordering of paramagnetic B2-$Fe_{60}Al_{40}$ causes an increase in the Fe-Fe nearest neighbours, leading to the formation of ferromagnetic (FM) A2-$Fe_{60}Al_{40}$ [1]. Here we present FM stripes and dots in B2-$Fe_{60}Al_{40}$ directly written with a highly-focused (2 nm) Ne^+ beam [2], and study the evolution of their magnetic domains with structure size. Domain imaging (using Scanning Transmission X-ray Microscopy and Magnetic Force Microscopy) shows the transition from irregular domains for the broadest stripes to well defined alternating domain structure for 500 nm wide stripes, and to a single domain state for widths below 100 nm. Similarly, dot structures exhibit a transition from a vortex to a single domain state. Our results show that thin-film $Fe_{60}Al_{40}$ is a model system for one-step patterning of well-defined FM nanostructures of desired geometries [2]. [1] Bali et al., Nano Lett. 14, 435 (2014) [2] Röder et al., Sci. Rep. 5, 16786 (2015)

MA 17.25 Tue 9:30 Poster B1

Spatially resolved ferromagnetic resonance (FMR) using X-rays and thermal excitation — •Taddäus Schaffers[1,2], Ralf Meckenstock[2], Detlef Spoddig[2], Andreas Ney[1], Christian Schöppner[2], Hendrik Ohldag[3], Stefano Bonetti[4], and Michael Farle[2] — [1]Johannes Kepler University Linz, Austria — [2]University of Duisburg-Essen, Germany — [3]SSRL, SLAC National Accelerator Laboratory, Menlo Park, CA — [4]Stanford University, CA, USA

In order to study local magnetic properties of micro-sized samples with FMR it is necessary to use a different kind of modulation or detection than in the conventional FMR measurements. By detecting the FMR with a microresonator it is possible to detect down to 10^6 spins [1]. Using thermal modulation instead of magnetic field modulation a spatial resolution of 110 nm is achieved and local magnetic properties are measured [2]. We combine thermal excitation with microresonator detection which enables us to study the influence of inhomogeneous stray fields on the FMR position and linewidth of two perpendicular Co-microstripes and compare the results to the integral detection. An alternative way to measure spatially resolved FMR is to change the detection mechanism from measuring the reflectected microwave power to using X-rays. By doing this it is possible to measure with a spatial resolution down to 35 nm [3].

[1]Narkowicz,et.al.,J. Magn. Res. **175**(2005)275
[2]Meckenstock, Rev Sci Instrum. **79**(2008).041101
[3]Bonetti,Rev Sci Instrum. **86**(2015)093703

MA 17.26 Tue 9:30 Poster B1

Development and Commissioning of a Multi-Frequency FMR Setup — •Martin Buchner, Taddäus Schaffers, and Andreas Ney — Johannes Kepler Universität, Linz, Austria

Ferromagnetic resonance spectroscopy is used to measure dynamic magnetic properties. Furthermore, a precise determination of the g-factor by analyzing the FMR signals' frequency dependence is possible [1]. Ferromagnetic excitation is achieved by inducing a microwave in the sample system (in this case a permalloy film). For microwave coupling commonly cylindrical resonators are used. However, the frequency range achieved by those is limited. In this contribution we present a setup which replaces the resonator by a coaxial cable that is short-circuited at one end and therefore exhibits standing wave behavior. At this end the microwave is induced into the sample. Thus, with the method shown, measurements in a wider frequency range are possible. A further advantage is the accessibility of the sample which enables to measure other properties like electric and magneto resistance as well as the inverse spin Hall effect as a measure for spin pumping at the same time.

[1] F. M. Römer et al. Appl. Phys. Lett. **100**, 092402 (2012).

MA 17.27 Tue 9:30 Poster B1

First-principles study of magnetic perovskite interfaces — •Igor Maznichenko[1], Arthur Ernst[2], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Materials with perovskite structure demonstrate a broad spectrum of physical properties. Colossal magnetoresistance, ferroelectricity, multiferroicity, superconductivity, charge ordering, metal-insulator transition, Jahn-Teller and other effects are observed in perovskites. These properties of the mentioned materials with the common formula ABO_3 are very sensitive to the type of the cations A and B. $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) is a strongly correlated 3d transition metal oxide with a Curie temperature (T_C) above RT (370 K). For other La/Sr ratios different types of antiferromagnetism are observed. Another perovskite - ruthenate, $SrRuO_3$ (SRO) is a 4d ferromagnet with T_C = 160 K. Two component perovskite superlattices have two different terminations due to the asymmetry AO/BO_2. In particular in LSMO/SRO superlattices this can be treated as a function of the Sr amount at one of interfacial LSMO layer. Using a first-principles Green function method within density functional theory, we examinate magnetic coupling at different interfaces.

MA 17.28 Tue 9:30 Poster B1

Investigation of 3*d*-5*d* double perovskites as potential room temperature multiferroics — •Shivani Gour[1,2], Vikas Shabadi[1], Philipp Komissinskiy[1], Rajeev Gupta[2], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Strasse 2, 64287 Darmstadt, Germany — [2]Materials Science Programme, Indian Institute of Technology Kanpur, India

In the search for multiferroic materials with ferromagnetic and ferroelectric order in a single phase, the A_2BBO_6 double perovskites hold the potential for room-temperature functionality. The fabrication challenge with these multi-cation complex oxides lies in the precise control of oxidation states of the elements and achieving a high degree of B-site chemical order. Based on recent theoretical investigations to identify potential ferromagnetic insulators among 3*d*-5*d* double perovskites, the compound Bi_2MnReO_6 was predicted to have magnetic ordering temperatures well above 300 K. We report on the fabrication of epitaxial thin films of the analogous novel Mn-Re based compounds on single crystal $SrTiO_3$ (001) substrates, using pulsed laser deposition. Given the specific configuration of the outer electronic shells and the close to 150° Mn-O-Re bond angle, the magnetic moments on Mn and Re are expected to be coupled via superexchange in a ferrimagnetic state. Detailed structural investigations were performed by X-ray diffraction and the magnetic properties were studied by SQUID magnetometry.

MA 17.29 Tue 9:30 Poster B1

Investigation of the symmetry reduction of erythrosiderites by single crystal X-ray diffraction — •Tobias Fröhlich[1], Daniel Brüning[1], Ladislav Bohatý[2], Petra Becker[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln

Erythrosiderites $A_2[FeX_5(H_2O)]$, where A stands for an alkali metal or ammonium ion and X for a halide ion, are antiferromagnets with Néel-temperatures ranging from 6 to 23 K [1]. This family of compounds allows to investigate the impact of structural parameters on the magnetoelectric properties by comparing their closely related structures as determined by single-crystal X-ray diffraction. The compound $(NH_4)_2[FeCl_5(H_2O)]$ was found to be multiferroic with strong magnetoelectric coupling [2]. The structures of $(NH_4)_2[FeCl_5(H_2O)]$ is investigated by single-crystal X-ray diffraction. The compound exhibits a phase transition to the multiferroic phase at $T_N \approx 7$ K. There exists a further structural transition at about 80 K. In the past, it was assumed that this transition is from space group $P\frac{2_1}{n}\frac{2_1}{m}\frac{2_1}{a}$ to $P11\frac{2_1}{a}$ [3]. However, recent macroscopic measurements indicate, that the structure becomes polar, with a polarization perpendicular to the c-axis. In this case, a symmetry reduction to P11a is predicted.

[1] J. Luzón et al., Physical Review B, **78**, 054414 (2008). [2] M. Ackermann, D. Brüning, T. Lorenz, P. Becker, L. Bohatý, New Journal of Physics **15**, 123001 (2013). [3] M. Ackermann, PhD-thesis (2014).

MA 17.30 Tue 9:30 Poster B1

Microscopic and spectroscopic investigation of self assembled Fe_4 single molecule magnets on surfaces — •Fabian Paschke[1], Philipp Erler[1], Peter Schmitt[2], Nicole Barth[1], Andreas Irmler[1], Thomas Huhn[2], Fabian Pauly[1], Luca Gragnaniello[1], and Mikhail Fonin[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]Fachbereich Chemie, Universität Konstanz, 78457 Konstanz

The investigation of single molecule magnets (SMMs) allows the observation of unique magnetic properties, such as pure molecular hysteresis and quantum tunneling of magnetization. The deposition of intact SMMs on suitable substrates as well as the investigation and control of their magnetic properties is a part of a promising route to molecular-based data storage or quantum computing applications.

Here we show the controlled deposition of an Fe_4 SMM by means of electrospray ionization on two different substrates, namely h-BN/Rh(111) and graphene/Ir(111). The organic ligand shell of the complex is tailored by choosing the shortest tripodal ligand possible, resulting in a highly ordered self-assembly of flat lying molecules, whose anisotropy axis is oriented perpendicular to the sample surface. Submonolayers and well-ordered monolayers of Fe_4 molecules are investigated by scanning tunneling microscopy and spectroscopy. Typical dI/dV spectra obtained around the Fermi energy are symmetrical with steps at energies of around 5 meV. We attribute these features to spin-excitations of the molecules due to a spin-flip of the tunneling electron.

MA 17.31 Tue 9:30 Poster B1

Correlation of the orbital moment with the local structure of CoOEP — •Nico Rothenbach[1], Katharina Ollefs[1], Andrei Rogalev[2], Fabrice Wilhelm[2], Francois Guillou[2], and Heiko Wende[1] — [1]University of Duisburg-Essen, Faculty of Physics and CENIDE — [2]European Synchrotron Radiation Facility (ESRF), ID12

We correlate the orbital magnetic moment of Co-octaethylporphyrin (CoOEP) molecules with its local geometric structure. This is achieved by means of combined XMCD and EXAFS study at the Co K-edge in the hard X-ray regime at the ESRF. The understanding of the magnetic interactions within molecular hybrid systems is essential for possible future applications e.g. for molecular spintronics [1]. Recently investigations of CoOEP on graphene/Ni(111) have shown a magnetic coupling via graphene to the Ni substrate. Sum rule analysis of XMCD spectra taken at the Cobalt $L_{2,3}$-edge revealed a ratio of orbital to spin moment of $\sim$ 55% [2,3]. To study the orbital moment of CoOEP we measured the Co K-edge XMCD which is only sensitive to the orbital moment due to the absence of the SOC in the initial 1s state. We carried out measurements on two different samples: On the one hand we pressed the molecules to a pellet and on the other hand, we droped an mixture of the molecules dissolved in ethanol on a Si-Substrate. To correlate these results for the magnetic properties to the local structure we performed EXAFS measurements at the Co K-edge.

[1] H. Wende, Nature Materials 8, 165 (2009)
[2] C. F. Hermanns et al., Adv. Mater. 25, 3473 (2013)
[3] D. Klar et al., Phys. Rev. B 89, 144411 (2014)

MA 17.32 Tue 9:30 Poster B1

Competing Spin-charge States in Electron-doped Triangular Molecular Magnets — •Rajyavardhan Ray[1,2] and Sanjeev Kumar[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden e.V. PO Box 270116, D-01171 Dresden, Germany — [2]Indian Institute of Science Education and Research (IISER) Mohali, Sector 81, SAS Nagar, Manauli PO 140306, India

We report a rich phase diagram of spin-charge coupled ground states for an electron coupled to the background of frustrated magnetic texture of a triangular molecular magnet (MM). These states arise out of interplay and competition between different energy scales of the problem. The ground state magnetic texture of the MM shows a reentrant behaviour with an exchange coupling dependent response for the electron.

MA 17.33 Tue 9:30 Poster B1

Visualisation of electric dipole matrix elements in Brillouin zone — •Ondřej Stejskal, Radek Ješko, Rudolf Sýkora, and Jaroslav Hamrle — IT4Innovations, VSB-Technical University of Ostrava, Czech Republic

Optic and magneto-optic properites of crystals are determined by the well-known Kubo formula [1] for direct inter-band transitions. It states that the absorption of a photon followed by the excitation of electron in solids is governed by electric dipole element $\langle i|p|f\rangle$, where $|i\rangle$, $|f\rangle$ are initial and final electron states and p is the momentum operator. In order to understand in detail the electric dipole elements, we visualise them in the reciprocal space on surfaces with constant energy difference between initial and final electron bands. It allows us to identify hot-spots contributing to the magneto-optic response. The dipole elements are calculated using Wien2k package [2] and visualised for nonmagnetic bcc W and ferromagnetic bcc Fe.

[1] C. Wang and J. Callaway, Phys. Rev. B 9, 4897 (1974)
[2] P. Blaha, K. Schwarz, G. Madsen, D. Kvasnicka and J. Luitz, WIEN2k, 2001

MA 17.34 Tue 9:30 Poster B1

Magnetic Imaging of Domain Wall Spin Structures in Fe Rings using SEMPA — Pascal Krautscheid[1,2], •Daniel Schönke[1], 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

For spintronic devices, a control over spin structures and an ability to manipulate magnetization dynamics is required. Here the geometrical control of the domain wall (DW) configuration in nanoscale Fe rings was investigated using scanning electron microscopy with polarization analysis (SEMPA) and micromagnetic simulations. Previous measurements for Co and Py showed a transition from a transverse to a vortex DW on increasing the ring size [1]. The observed vortex wall configuration is accessible in a large range of ring sizes in Fe, with the experimental phase boundary found to be close to the one representing the global energy minimum. It is found that the transverse wall phase boundary is shifted to smaller dimensions for Fe than for Py. For state manipulation, spin accumulation (SA) generated by electrical currents has gained interest due to possibilities for switching the magnetization state of a device. With recent work showing that such SA can be detected via X-ray imaging [2], the future application of SEMPA to image such SA is a promising avenue with the surface sensitivity of the technique expected to be advantageous [3]. [1] M. Kläui, J. Phys.: Condens. Matter 20 (2008). [2] Kukreja et al., Phys. Rev. Lett. 115, 096601 (2015).* [3] Zhang et al., Sci. Rep. 4, 4844 (2014).

MA 17.35 Tue 9:30 Poster B1

Design 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], and Ulf Berges[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 a new design of a Scanning Reflection X-ray Microscope (SRXM) based on zone plate imaging in the extreme ultraviolet (EUV) spectral range at the DELTA beamline 12 optimized for the 3p absorption edges of 3d transition metals. The operation in reflection mode will allow magnetic domain imaging in buried layers exploiting magneto-optical reflection spectroscopy employing T-MOKE, L-MOKE, XMLD and XMCD [1] as magnetic contrast mechanisms. In contrast to transmission, the STXM geometry will allow the study of buried layers, layer systems and interfaces on surfaces even of thick samples. The advantage of the EUV spectral range over the soft X-ray range is the increased reflectance which is about two orders of magnitude larger than at the 2p edges. [1] M. Tesch, M. Gilbert, H - Ch. Mertins, D. Bürgler et al., Appl. Opt. 52, 4294 (2013)

MA 17.36 Tue 9:30 Poster B1

Anisotropic magneto-optical properties of ultrathin Fe/GaAs(001) layers — •Martin Buchner[1], Sebastian Putz[1], Stefan Günther[2], Matthias Kronseder[1], Dieter Schuh[1], Dominique Bougeard[1], Jaroslav Fabian[1], and Christian Back[1] — [1]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Department of Materials, ETH Zürich, 8093 Zürich, Switzerland

Spin-orbit coupling plays an important role in solids lacking space inversion symmetry. It has been shown that the resulting interfacial spin-orbit fields at the Fe/GaAs(001) interface lead to several anisotropic electronic properties like tunneling anisotropic magnetoresistance [1] as well as lateral anisotropic magnetotransport phenomena [2].

Recently, it has been proposed that the anisotropic interfacial spin-orbit fields also should affect the optical properties of the Fe/GaAs(001) heterostructure [3]. Here, we report the observation of anisotropic polar magneto-optical Kerr effect in epitaxial Fe/GaAs(001). We observe a clear twofold symmetry of the Kerr rotation angle depending on the orientation of the linear polarization of the probing laser beam with respect to the crystallographic directions of the sample.

[1] J. Moser et al., Phys. Rev. Lett. 99, 056601 (2007).
[2] T. Hupfauer et al., Nat. Commun. 6, 7374 (2015).
[3] S. Putz et al., Phys. Rev. B 90, 045315 (2014).

MA 17.37 Tue 9:30 Poster B1

Skyrmions and spin spirals in canted and in-plane magnetic fields investigated by STM — •Lorenz Schmidt, Pin-Jui Hsu, Andrè Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, Universität Hamburg

Ultrathin magnetic films can exhibit topologically non-trivial spin textures as a result of competing magnetic interactions. Previous spin-polarized scanning tunneling microscopy experiments showed that an atomic bilayer of palladium and iron on Ir(111) shows spin spirals in zero field and the application of a perpendicular magnetic field leads to the formation of skyrmions [1,2].

Here we investigate the changes caused by in-plane magnetic fields in skyrmions and spin spirals with STM in a vectorial magnetic field by making use of non-collinear magnetoresistance contrast [3]. The canted magnetic field induces an asymmetry in the skyrmion, breaking its rotational symmetry. This allows to determine the cycloidal nature of the skyrmion and its sense of rotation.

[1] N. Romming *et al*, Science **341**, 636 (2013)
[2] N. Romming *et al*, Phys. Rev. Lett. **114**, 177203 (2015)
[3] C. Hanneken *et al*, 10.1038/NNANO.2015.218 (2015)

MA 17.38 Tue 9:30 Poster B1

Study of the magnetic properties of spin waves in thin Yttrium Iron Garnet films. — •Oleksandr Talalaevskyy[1], Martin Decker[1], Johannes Stigloher[1], Arpita Mitra[2], Christian Back[1], and Bryan Hickey[2] — [1]University of Regensburg, Regensburg, Germany — [2]University of Leeds,Leeds, UK

Yttrium Iron Garnet (Y3Fe5O12) is one of the most promising materials for studying high frequency magnetization dynamics. Due to its extremely low Gilbert damping parameter which can reach values of 1*10-5 for YIG spheres.Experiments with spin waves propagation are very important for understanding magnetization dynamics. In particular interest has recently increased since thin YIG films of reasonably high quality can nowadays be prepared by pulsed layer deposition or sputter deposition. Thin YIG can be used for effective excitation of the autooscillations by running a current through a Pt layers deposited on top of the film. We present an experimental study of the spin wave excitation and propagation in YIG stripes prepared by the magnetron sputtering. We report the time resolved magneto-optic Kerr effect measurements of spin waves(SW) parameters in thin YIG films. The mode structure of the spin waves is studied in dependence on the external magnetic film thickness and width of the stripe. We are able to detect a SW signal for distances up to 150 μm away from the CPW for narrow (2 μm) stripes.We calculate the spin wave attenuation length of the first mode for 50 nm and 40 nm thick samples. Furthermore we study the dependence of the maximal spin wave propagation length as function of the width of the stripe.

MA 17.39 Tue 9:30 Poster B1

Influence of oxygen content on magnetic properties in La1/2Sr1/2MnO3-δ thin films — Lei Cao[1], •Alexander Weber[2], Oleg Petracic[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, Garching

Complex oxides have a variety of promising applications ranging from sensors and spintronic devices to multifunctional materials. Most relevant future materials for e.g. electronics and photovoltaics are based on oxides. However, the influence of the oxide content after sample preparation on the physical properties is mostly unknown. We report on the fabrication of La1/2Sr1/2MnO3-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 varying oxygen atmospheres and at various temperatures. By employing SQUID magnetometry we then study the magnetic properties of the annealed systems. We thus relate the influence of oxygen absorption/desorption to the magnetic properties. Both Tc and the shape of the magnetic hysteresis turn out to depend on the oxygen stoichiometry.

MA 17.40 Tue 9:30 Poster B1

High-T_C Interfacial Magnetism in $(LaMnO_3)_{2n}/(SrMnO_3)_n$ **and** $(La_2CoMnO_6)_{2n}/(SrMnO_3)_n$ **Superlattices** — •Marius Keunecke[1], Sven Esser[1], Danny Schwarzbach[1], Markus Jungbauer[1], Sebastian Hühn[1], Vasily Moshnyaga[1], Ricardo Egoavil[2], Gustaf Van Tendeloo[2], Nicolas Gauquelin[2], Johan Verbeeck[2], Kerry O'Shea[3], and Donald MacLaren[3] — [1]I. Physikalisches Institut Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]EMAT, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium — [3]Scottish Universities Physics Alliance, School of Physics and Astronomy, University of Glasgow, Glasgow, Glasgow G12 8QQ, UK

Superlattices of $(LaMnO_3)_{2n}/(SrMnO_3)_n$ (LMO/SMO, n=6) and $(La_2CoMnO_6)_{2n}/(SrMnO_3)_n$ (LCMO/SMO, n=5) on $SrTiO_3$ (001) were prepared by a metalorganic aerosol deposition technique (MAD). A high structural quality of samples was evidenced by XRD, XRR and TEM. SQUID magnetization measurements for the LMO/SMO SLs clearly show two ferromagnetic (FM) phases with $T_{C1} \approx 230K$ and $T_{C2} = 358K$. The low-temperature phase is likely located in the LMO layers. The high-temperature FM phase might originate from the LMO/SMO interface due to the electron transfer across the interface. No high-T_C phase and no interfacial charge transfer was found in LCMO/SMO. By introducing a LMO buffer layer with sufficient thickness (6 ML) between both interfaces the high temperature interfacial FM phase can be restored. Financial support of the EU FP7 (Project *IFOX*) and SFB 1073 (TPB04) is acknowledged.

MA 17.41 Tue 9:30 Poster B1

Experimental Analysis of the Anomalous Hall Effect Arising from Noncollinear Antiferromagnetism in MnIr Thin Films — •Jan Krieft[1,2], Christian Sterwerf[1,2], Karsten Rott[1,2], Jan-Michael Schmalhorst[1,2], and Günter Reiss[1,2] — [1]Physics Department, Bielefeld University, 33615 Bielefeld, Germany — [2]Center for Spinelectronic Materials and Devices , Universitätsstrasse 25, 33615 Bielefeld, Germany

First-principles electronic structure calculations and symmetry arguments predict a large anomalous Hall conductivity in Mn3Ir due to a noncollinear antiferromagnetic structure. Based on field cooling in a high field cryostat, we verified the existence of a small scale anomalous Hall effect in a high-temperature antiferromagnet, which is therefore not proportional to the classical magnetization. In this work, we report on an anomalous Hall effect occurring, however it is smaller than theoretically predicted.

MA 17.42 Tue 9:30 Poster B1

Antiferromagnetic properties of Mn2Au thin films and exchange bias of Fe/Mn2Au heterostructures — •Alexey Sapozhnik[1,2], Simone Finizio[3], Radu Abrudan[4], Anton Devishvili[5], Mathias Kläui[1], Hans-Joachim Elmers[1], Hartmut Zabel[1], and Martin Jourdan[1] — [1]Institut für Physik, JG Universität, Mainz, Germany — [2]MAINZ Graduate School, Germany — [3]PSI, Switzerland — [4]HZB, Germany — [5]Uppsala University, Sweden

Large efforts are being made to implement spintronic devices based on antiferromagnets (AFM). Metallic AFMs such as Mn2Au are attractive because of their potential manipulation via currents. Here we report magnetic properties of Mn2Au and Fe/Mn2Au revealed by MOKE, resonant magnetic x-ray and polarized neutron techniques. X-PEEM on high-quality epitaxial Fe/Mn2Au (001) films exhibits ~1mkm size Fe domains imprinted by AFM domains in Mn2Au. Mn-L3 XMLD suggests that these domains are preferentially oriented along the inplane [110] AFM easy axis. However, the very high Néel temperature prevents the domain distribution manipulation. To overcome these problems, Fe/Mn2Au films were deposited at lower substrate temperature, which effectively decreases the crystal grain size and lowers the Néel temperature. Upon field cooling a significant exchange bias effect is observed, in contrast to heterostructures grown at higher temperatures. Temperature dependent hysteresis loops exhibit asymmetric reversal behavior. Polarized neutron reflectivity confirms domain wall motion at negative coercivity, but partial rotation at positive coercivity.

MA 17.43 Tue 9:30 Poster B1

Growth of Pb on ultrathin Fe layers on Ir(111) — •Jonas Sassmannshausen, André Kubetzka, Niklas Romming, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, 20355 Hamburg, Germany

Recently, it was found that a monolayer of iron (Fe) on an iridium substrate (Ir(111)) shows a square lattice of skyrmions, even in zero external magnetic field [1]. This skyrmion lattice can be converted into a spin spiral ground state by covering it with a layer of palladium (Pd) [2].

Here, instead of Pd we deposit an adlayer of lead (Pb), for which high spin-orbit coupling at the Fe-Pb interface can be expected. We investigate the growth of Pb on ultrathin Fe layers on Ir(111) by means of scanning tunneling microscopy. For a preparation well above room temperature we observe intermixing of Pb and Fe. We vary the film thickness as well as the substrate temperature to optimize the Pb film quality. Our results show that temperatures below 300 K reduce alloying and improve the formation of well defined Pb overlayers.

[1] S. Heinze *et al.*, Nature Phys. **7**, 713 (2011)
[2] N. Romming *et al.*, Science **341**, 6146 (2013)

MA 17.44 Tue 9:30 Poster B1

Stripe domain patterns in non-centrosymmetric ultrathin Fe/Ni-films on Cu(001) — •Thomas Meier, Matthias Kronseder, Michael Zimmermann, and Christian 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 dipole interaction leads to the formation of stripe domain patterns in the vicinity of the spin reorientation transition. Here, we investigate fluctuations of domain patterns in ultrathin epitaxial Ni/Fe-bilayer- and trilayer-films grown on Cu(001) using the technique of threshold photoemission magnetic circular dichroism in combination with photoemission electron microscopy allowing real-time observation of the domain pattern and its dynamics. The breaking of the inversion symmetry by the interfaces leads to the emergence of the Dzyaloshinski-Moriya-interaction (DMI). Here we analyze the influence of the DMI on the domain pattern and develop an improved domain model including the DMI based on the theory of Kashuba et al. (Phys. Rev. B 48(14), 10335), which describes the evolution of the domain width depending on the perpendicular anisotropy. Furthermore we analyze the strength of fluctuations with respect to temperature and externally applied out-of-plane magnetic fields.

MA 17.45 Tue 9:30 Poster B1

Investigation on new TMR stacks for inverse magnetrostrictive sensors — •Niklas Dohmeier[1], Günter Reiss[1], Karsten Rott[1], Ali Tavassolizadeh[2], Dirk Meyners[2], Eckhard Quandt[2], and Hendrik Hölscher[3] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute for Materials Science, Christian-Albrechts-Universität zu Kiel — [3]Institute of Microstructure Technology, Karlsruhe Institute of Technology (KIT)

We show new TMR stacks for magnetostrictive sensors based on *CoFeB / MgO / CoFeB* tunnel junctions.
With a free *CoFeB* layer the direction of its magnetization is not well defined, as in the earlier stacks.
Therefore, in order to achieve the highest sensitivity, a bias field is required to set the magnetization of the free layer at the optimum direction.
CoFeB layers. Below the barrier the exchange bias is induced via the antiferromagnet *MnIr*. The upper part is pinned with an artificial antiferromagnet consisting of *MnIr* and *CoFe* layers.
Via two consecutively field coolings with different temperatures and field orientations exchange bias in different directions was achieved.
These TMR stacks have been made by magnetron sputtering and investigated by magneto-optical Kerr effect (MOKE), TMR measurements and four point bending experiments.

MA 17.46 Tue 9:30 Poster B1

Voltage-Induced Magnetic Manipulation of a Microstructured Iron Gold Multilayer System — •Robert Sittig — Max Planck Institute for Intelligent Systems — Universität Stuttgart

This work was aimed at developing a microstructured system of ultra thin iron for voltage-induced magnetic manipulation.

For this purpose a layer sequence with capacitor geometry, based on a central MgO/Fe/Au-junction, is proposed. First, the quality of the materials, deposited on Si-substrate via sputter coating, is checked carefully with multiple characterization methods. Then a 5-step microstructuring pattern is designed for proper electronic connection. The corresponding lithographic processes are realized in a direct laser writer system and accordingly optimized. With the completed samples, the effect of static and pulsed electric fields on the magnetic film are studied in a MOKE microscope.

This work holds prospects for application in low-power spintronics and non-volatile data storage along with possible service as magnon source.

MA 17.47 Tue 9:30 Poster B1

Free-Standing Thin Films of Magnetic Intercalated Dichalcogenides studied by XMCD and ultrafast TEM — •Thomas Danz[1], Qi Liu[2], Ra'anan I. Tobey[2], Sascha Schäfer[1], and Claus Ropers[1] — [1]4th Physical Institute, University of Göttingen, Germany — [2]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands

Transition metal dichalcogenides (TMDCs) represent a broad class of layered materials with a variety of intrinsic structural and electronic properties. These properties can be further diversified by intercalation of atoms and small molecules between the loosely bound layers. In particular, the intercalation of $3d$ transition metals results in an array of magnetic properties. Therefore, $3d$ intercalated TMDCs provide a platform to study magnetic, structural, and electronic dynamics with tunability by concentration, intercalated species, and host lattice [1]. Here, we present a sample preparation technique providing large area, free-standing films of $3d$ intercalated TMDCs down to a thickness of 30 nm. The properties of the initial bulk samples are largely retained, as evidenced by static TEM diffraction and XMCD measurements [2]. Furthermore, first results of optical pump/electron probe measurements on the ultrafast sample dynamics in the Göttingen Ultrafast Transmission Electron Microscope (UTEM) [3] will be presented.

[1] W. Y. Liang, in: Intercalation in Layered Materials, M. S. Dresselhaus (Ed.), Springer, pp. 31–73 (1986).
[2] Th. Danz *et al.*, in preparation.
[3] A. Feist *et al.*, Nature **521**, 200 (2015).

MA 17.48 Tue 9:30 Poster B1

Temperature and magnetic field dependent Raman spectroscopy on thin $(La_{0.65}Pr_{0.45})_{0.7}Ca_{0.3}MnO_3$ films — •Sebastian Merten[1], Oleg Shapoval[2], Bernd Damaschke[1], Konrad Samwer[1], and Vasily Moshnyaga[1] — [1]I. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [2]IIEN, Academy of Science of Republic Moldova, Academia 3/3, MD-2028 Chinisau, Republic of Moldova

Mixed-valence manganites are still in the focus of fundamental research due to their rich phase diagram and intriguing phenomena like the colossal magnetoresistance (CMR). Crucial for understanding the physics of the manganites is the strong electron-phonon coupling manifested as the Jahn-Teller (JT) effect. To study the strong coupling between electrons and phonons, we performed Raman spectroscopy on $(La_{0.65}Pr_{0.45})_{0.7}Ca_{0.3}MnO_3$ thin films (λ = 532 nm, P = 2.9 mW) as a function of temperature and applied magnetic field. We observed four pronounced modes at 235 cm^{-1}, 434 cm^{-1}, 485 cm^{-1} and 609 cm^{-1} where the last two arise from the JT effect. The temperature as well as magnetic field dependent Raman spectra show a disorder-order transition observable as an abrupt intensity decrease of the JT modes and a strong increase of the phonon mode at 434 cm^{-1}. This behaviour correlates well with the metal-insulator transition and the CMR effect thus demonstrating a strong change of the electron-phonon coupling at the phase transition and its importance for the CMR effect. Financial support from SFB 1073 (TP B04) is acknowledged.

MA 17.49 Tue 9:30 Poster B1

Nanostructuring on MnSi thin films — •David Schroeter[1], Nico Steinki[1], Patryk Krzysteczko[2], Alexander Fernández Scarioni[2], Peter Krebs[2], Hans Werner Schumacher[2], Stefan Süllow[1], and Dirk Menzel[1] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

The chiral magnet MnSi, which crystallizes in the cubic B20 structure, has evoked much interest due to the existence of skyrmions. Furthermore the material shows an extended magnetic phase diagram when introduced to a reduction of the dimensionality of the system. Therefore it is of great interest to analyze nano-sized MnSi in form of thin films and nano wires.
We have grown high quality thin films via molecular beam epitaxy and structured them using electron beam lithography. Hall bar structures with widths between 100 nm and 10 μm have been produced and characterized regarding their structural properties. First measurements of the electrical and magnetical characteristics have been started. The results will be presented and deviations from three and two dimensional material will be discussed.

MA 17.50 Tue 9:30 Poster B1

Improvement of the epitaxial growth of MnSi thin films — •Patricia Herbst[1], David Schroeter[1], Peter Krebs[2], Dirk Thorsten Dziomba[2], Stefan Süllow[1], and Dirk Menzel[1] — [1]Institut für Physik der Kondensierten Materie, Technische Universität Braunschweig, Braunschweig, Germany — [2]Physikalisch Technische Bundesanstalt, Braunschweig, Germany

The challenge to increase the data storage density in information technology combined with an improvement of data processing requires new concepts of spin-electronic devices. One possible route is the creation of functionalites which utilize magnetic skyrmions. Nano-sized B20 MnSi in form of thin films and quantum wires offers a high potential to promote such future technology, not least as the magnetic phase diagram shows an enlarged skyrmionic phase compared to bulk. The structural and morphological quality of the required films is of great importance. Therefore, it is mandatory to establish growth techniques which provide for reliable and reproducible outcome of high grade. In this work MnSi thin films have been grown via molecular beam epitaxy and characterized using AFM and SQUID measurements. Films with 30 nm thickness show a RMS surface roughness of 3 nm compared to prior results with considerably poor surface morphology. The enhanced film quality makes it now possible to observe and identify clearly the magnetic phase transitions from simple magnetization measurements.

MA 17.51 Tue 9:30 Poster B1

Observation of an optically induced magnetic vortex glass in an iron thin film — •Tim Eggebrecht[1], Marcel Möller[2], Jan Gregor Gatzmann[2], Nara Rubiano da Silva[2], Armin Feist[2], Ulrike Martens[3], Konrad Samwer[1], Markus Münzenberg[3], Claus Ropers[2], and Sascha Schäfer[2] — [1]I. Physikalisches Institut, Universität Göttingen — [2]IV. Physikalisches Institut, Universität Göttingen — [3]Grenz- und Oberflächenphysik, Universität Greifswald

In this work, we show the generation of magnetic defect states in an ultrathin iron/silicon-nitride bilayer after optical excitation with ultrashort laser pulses. Above a well-defined threshold in laser intensity, the initial magnetic ripple structure transforms on micrometer scales into a dense interwoven network of localized vortices and antivortices with glass-like properties.

Magnetic structures are mapped by transmission electron microscopy (TEM) with Lorentz contrast, where out-of-focus imaging conditions give access to the transverse sample magnetization. The electron microscope is modified to allow for in-situ femtosecond laser excitation.

We analyze the vortex-antivortex network structure, its charateristic length scales and discuss the appearance of topologically protected defects in a rapid heating and quenching model. In particular, possible contributions from the Kibble-Zurek mechanism and subsequent vortex-antivortex annihilation pathways are considered.

We acknowledge support by the DFG via SFB 1073/projects A05 and B01.

MA 17.52 Tue 9:30 Poster B1

Magnetic and magnetoelastic properties of NiCoMnAl-shape memory Heusler alloys — •Andreas Becker and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Magnetic shape memory alloys offer a large variety of functionality. Magnetic Materials, which undergo a first order phase transformation, are especially needed in magnetocaloric cooling, because they exhibit a large temperature and entropy change upon magnetic loading. Such materials often consist of rare materials and are therefore not suitable for commercial applications.

Measurements reveal, that NiCoMnAl-Heusler-alloys thin films, grown on an MgO-Substrate or a Vanadium buffer layer by sputtering deposition, achieve a large magnetocaloric effect, while consisting of common elements. The aim of our research is to investigate the magnetic and magnetoelastic properties of austenite films. To measure the induced strain, caused by the martensitic phase transition and the spinpolarization, TMR-junctions are grown and fabricated by e-beam lithography on top of the Heusler alloy films. Additionally, temperature dependent XRD-measurements of different compositions will be presented.

MA 17.53 Tue 9:30 Poster B1

Magnetic Properties of Layered Chromium Trihalides — •Nils Richter[1,2], Franziska Racky[1], Daniel Weber[3], Clemens Wuth[4], Bettina V. Lotsch[3], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ) — [3]Max-Planck Institut für Festkörperforschung Nanochemistry Stuttgart — [4]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

There is an ever-growing interest in two-dimensional materials to facilitate further size-reduction and enhanced efficiency in microelectronics [1]. Especially magnetic properties of such materials are important for spintronic and magnetoelectronic applications [2]. The class of chromium trihalides, CrX_3 (X = Cl, Br, I), are van der Waals bonded, layered semiconductors and show (anti-)ferromagnetism [3]. We examine the magnetic properties of large crystallites of these compounds using a superconducting quantum interference device (SQUID). Furthermore we are able to exfoliate all of them with thicknesses down to a few layers. We test these ultra-thin systems of just a few layers, whether their magnetism persists on this scale by probing their magnetic stray field with ballistic Hall-sensors made of high-mobility GaAs/AlGaAs 2DEGs[4].

[1] Lemme, M. C. et al., F. MRS Bull. 39 (2014). [2] Felser, C. et al., Angew. Chem., Int. Ed. 46 (2007). [3] Wang, H. et al., J. Phys. Condens. Matter 23 (2011). [4] A. K. Geim et al., Appl. Phys. Lett. 71 (1997).

MA 17.54 Tue 9:30 Poster B1

Effect of microstructure on the magnetic properties of transition metal implanted TiO2 films — •Oguz Yildirim[1], Steffen Cornelius[1,2], Maik Butterling[1], Wolfgang Anwand[1], Andreas Wagner[1], Alevtina Smekhova[3,4], René Hübner[1], Roman Böttger[1], Jan Fiedler[1], Carsten Bähtz[5], and Kay Potzger[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany — [2]Delft University of Technology, Department of Chemical Engineering, Materials for Energy Conversion and Storage, Delft, The Netherlands — [3]Lomonosov Moscow State University (MSU) Moscow, Russia — [4]University of Duisburg-Essen, Faculty of Physics and CENIDE Duisburg,Germany — [5]Rossendorf Beamline, European Synchrotron Radiation Facility Grenoble, France

The origin of the ferromagnetic order in TM:TiO2 (TM: transition metal) systems is studied by investigating the interplay between structural order, defects and incorporation of implanted TM ions within the host lattice. The defect properties of the host TiO2 films are altered by preparing different microstructures of TiO2 (e.g. amorphous, polycrystalline anatase and epitaxial anatase). The difference in microstructure is also found to influence the incorporation of the implanted ions into the host lattice. The crystallographic incorporation of the implanted TM atom is found only in crystalline films. Moreover, it is observed that the suppression of the dopant related secondary phases can also be achieved by changing the microstructure. Based on this discussion we propose an ideal microstructural candidate for a dilute magnetic oxide material based on our results.

MA 17.55 Tue 9:30 Poster B1

Electronic-transport characterization of (Ga,Mn)As thin films — •Jan Teschabai-Oglu[1], Martin Lonsky[1], Klaus Pierz[2], Hans Werner Schumacher[2], and Jens Müller[1] — [1]Physikalisches Institut, Goethe-Universität, Frankfurt (M), Germany — [2]Physikalisch-Technische Bundesantalt, Braunschweig, Germany

A semiconductor, which is also a ferromagnet, may be used in spintronic applications, where logic and memory operations could in principle be integrated on a single device. Subject of our research is the semiconductor (Ga,Mn)As, where ferromagnetism is induced by a high concentration of magnetic elements (Mn) in the host GaAs matrix. Inspired by recent results of a diverging $1/f$-noise level in the ferromagnetic semimetal and colossal magnetoresistance material EuB6 [1], where the existence of percolating nanoscale magnetic clusters is established, we perform systematic studies of fluctuation (noise) spectroscopy on epitaxial thin films of (Ga,Mn)As [2] with different growth parameters. We present results of the (magneto-)resistivity and both ordinary and anomalous Hall effect to characterize the electronic (magneto-)transport properties. These studies are complemented by measurements of the resistance and Hall resistance noise yielding intrinsic $1/f$-type or Lorentzian power spectral densities. We discuss the temperature and magnetic field dependences of the noise in terms of carrier number and/or mobility fluctuations.

[1] P. Das et al., Phys. Rev. B 86, 184425 (2012)
[2] A. B. Hamida et al., Phys. Stat. Solidi B 251, 1652 (2014)

MA 17.56 Tue 9:30 Poster B1

Superexchange Interactions in Double Perovskite Osmates — •Ryan Morrow[1,2], Rohan Mishra[1], Oscar D. Restrepo[1], Molly R. Ball[1], Wolfgang Windl[1], Jennifer R. Soliz[1], Adam J. Hauser[1], James C. Gallagher[1], Michael A. Susner[1,4], Michael D. Sumption[1], Fengyuan Yang[1], Sabine Wurmehl[2,3], Ulrike Stockert[2,3], Bernd Büchner[2,3], Adam A. Aczel[4], Jiaqiang Yan[4], Michael A. McGuire[4], John W. Freeland[5], Daniel Haskel[5], and Patrick M. Woodward[1] — [1]OSU, Columbus, OH, United States — [2]IFW, Dresden, Germany — [3]TUD, Dresden, Germany — [4]ORNL, Oak Ridge, TN, United States — [5]ANL, Argonne, IL, United States

Double perovskites containing rock salt ordered 3d and 4d/5d cations have been intensely studied for their wide range of technologically relevant properties. Design of functional materials in the insulating state, where magnetic properties are dictated by superexchange interactions, remains challenging however due to the poorly understood competition between numerous potential exchange pathways. In this work, a number of insulating double perovskite osmates, A2BOsO6 (A=Sr,Ca,La; B=Cr,Fe,Co,Ni) have been chosen and studied using magnetometry, specific heat, XMCD, and neutron powder diffraction techniques in order to systematically probe the effects of electronic configuration and bonding geometry on the magnetic ground state. It is concluded that the magnetic ground state is controlled by a tunable competition between short range and long range superexchange interactions which are sensitive to electronic configuration and bonding geometry.

MA 17.57 Tue 9:30 Poster B1

Charge-spin-lattice correlations in the half-metallic CMR material $HgCr_2Se_4$ — •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, including hexaborides, remains a challenging field of research in magnetism. The universal occurrence of electronic and magnetic phase separation in these materials has led researchers to suggest the intriguingly simple model of percolating magnetic polarons as a possible mechanism to explain the CMR. In a recent study on the ferromagnetic semimetal EuB_6, where the existence of percolating nano-scale magnetic clusters is established, we found a very large lattice response at the ferromagnetic transition, a significant part of which originates in the magnetically-driven delocalization of charge carriers [1]. Inspired by these results we performed high-resolution thermal expansion and magnetostriction measurements on the half-metallic CMR material $HgCr_2Se_4$ [2], where the paramagnetic to ferromagnetic transition at 105K drives an insulator-to-metal transition with an 8-orders-of-magnitude decrease of the longitudinal resistivity (MR effect: $7 \cdot 10^4$ at 8T and 110K!). 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 113, 067202 (2014); [2] Guan et al., PRL 115, 087002 (2015)

MA 17.58 Tue 9:30 Poster B1

Synthesis and Characterization of intermetallic $Fe_xMn_{3-x}Si$ (x = 0-2) — •Sebastian Selter[1], Ahmad Omar[1], Christian G. F. Blum[1], Bernd Büchner[1,2], and Sabine Wurmehl[1,2] — [1]Leibniz Institute for Solid State and Materials Research IFW, D-01171 Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden, D-01062 Dresden, Germany

The class of Heusler compounds exhibits a plethora of remarkable properties. Recently, special interest arised in magnetocaloric properties found in selected Heusler compounds. The magnetocaloric effect may be related to a metamagnetic transition which is understood to evolve as a result of the interplay between co-existing ferromagnetic and antiferromagnetic interactions. The Fe-Mn-Si system is promising to observe this effect, due to the magnetism of the parent compounds, which exhibit both ferromagnetism (Fe_2MnSi) and antiferromagnetism (Mn_3Si).

A substitution series between the two materials was prepared by arc-melting stoichiometric amounts of the respective elements. Samples were characterized as-cast as well as after an additional annealing step at 900 °C for 3 days followed by quenching in water.

Consequently, the effect of substitution on the magnetic behavior in this system is discussed and set in context to the microstructure and phase evolution of the series.

MA 17.59 Tue 9:30 Poster B1

Magnetocrystalline anisotropy in nearly-compensated Mn2RuxGa — •Ciaran Fowley[1], Karsten Rode[2], Davide Betto[2], YongChang Lau[2], Naganivetha Thiyagarajah[2], Gwenael Atcheson[2], Jürgen Lindner[1], Jürgen Fassbender[1,3], Alina Deac[1], and Mike Coey[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf — [2]Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN), Trinity College Dublin, Dublin 2, Ireland — [3]Institute for Physics of Solids, TU Dresden, Dresden, Germany

Mn2RuxGa (MRG) has recently been shown to be a zero-moment ferrimagnetic half-metal, when x ~ 0.5 [1]. When grown on a TiN buffer, directly on a (001)-SrTiO3 substrate, the magnetic easy-axis is perpendicular to the film plane. The moments of the two Mn sub-lattices 4a and 4c, will only be precisely compensated at a fixed temperature because the temperature dependence of the 4c sublattice is much greater than that of the 4a sublattice [2]. For the present sample Tcomp = 350 K, giving a small net magnetization of 50 kA/m at room temperature. We have measured the transverse Hall resistance (Rxy) on samples patterned into Hall bars as a function of external field applied at an angle, θ, to the film normal. We fit the data obtained to a generalised Sucksmith-Thompson (GST) model [3], in order to extract values of the magnetic anisotropy constants K1 and K2. References: [1] Kurt H, et al., PRL 114, 027201 (2014), [2] Betto D et al., PRB 91, 094410 (2015), [3] Sucksmith W and Thompson JE, Proc. R. Soc. London, Ser. A 225, 362 (1954).

MA 17.60 Tue 9:30 Poster B1

High-throughput screening for antiferromagnetic Heusler compounds using density functional theory — •Jan Balluff, Markus Meinert, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Due to the exchange bias effect antiferromagnetic compounds are of particular interest for the field of spintronics. Since Heusler alloys are a very versatile family of compounds, searching for new, promising antiferromagnetic materials within this family is reasonable. Here, we report on a high-throughput screening among the Heusler compounds for systems with an antiferromagnetic ground state. Starting from a detailed evaluation of raw magnetic data for Heusler compounds extracted from the AFLOWLib, which contains data for more than 300,000 Heusler compounds, we determine possible candidates by means of formation energy and convex hull calculations. Further examination is done by explicit comparision of ferromagnetic / antiferromagnetic ground state calculations.

MA 17.61 Tue 9:30 Poster B1

Preparation and characterization of TiN buffered Co_2FeAl thin films — •Jana Ludwig, Alessia Niesen, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

TiN buffered Co_2FeAl thin films were prepared via DC magnetron sputtering. The TiN seed-layers (30 nm thickness) were deposited on MgO (001) and $SrTiO_3$ (001) substrates at a deposition temperature of 405°C in a mixture of Ar and N_2 atmosphere and a pressure of $p = 1.6 \cdot 10^{-3}$ mbar. A composit target was used to deposit the Co_2FeAl layers. The Ar-pressure was set to $p = 2.3 \cdot 10^{-3}$ mbar and the deposition of Co_2FeAl was carried out at room temperature. 2 nm thin MgO layers were deposited on top to prevent the samples from degradation. The crystallographic properties of Co_2FeAl and TiN were determined via x-ray diffraction and x-ray reflection measurements. $B2$ crystalline ordering was confirmed even for the as deposited state. The film thicknesses were varied between 10 nm and 0.8 nm in order to obtain and investigate in- and out-of-plane magnetized Co_2FeAl layers. Post annealing processes with temperatures up to 500°C were carried out in order to investigate the influence on the magnetic and structural properties. The magnetic properties of TiN buffered Co_2FeAl were investigated via MOKE measurements and revealed high perpendicular magnetic anisotropy for the 0.9 nm thin layers. The coercive fields increased with increasing post annealing temperature to 350 Oe and squareness ratios of 1 for temperatures above 300°C. The thermal stability was confirmed for temperatures up to 500°C.

MA 17.62 Tue 9:30 Poster B1

Structural, Optic and Magneto-Optic Properties of $NdFeO_3$ and $PrMn_{1-x}Fe_xO_3$ — •RadekJeško[1], Ondřej Stejskal[1], Robin Silber[1,2], Matúš Mihálik[3], and Jaroslav Hamrle[1] — [1]IT4Innovations and Nanotechnology Centre, VSB-Technical University of Ostrava, Czech Republic — [2]Faculty of Physics, Bielefeld University, Germany — [3]Institute of Experimental Physics, Slovak Academy of Science, Košice, Slovak Republic

Orthorhombic perovskites are nowadays broadly studied materials due to their tuneable magnetic and electric properties. Here we study $NdFeO_3$ and $PrMn_{1-x}Fe_xO_3$ bulk poly and monocrystals. They were prepared by floating zone technique from sintered powder oxides precursors in adequate stoichiometric amounts and their structure was determined by x-ray diffraction. Their optic and magneto-optic properties were obtained by spectroscopic ellipsometry and magneto-optic spectroscopy, providing full spectral permittivity tensor in extended visible range of energies.

MA 17.63 Tue 9:30 Poster B1

High frequency ferromagnetic resonance study of Heusler compounds using a micro-cantilever — •Alexey Alfonsov[1,2], Eiji Ohmichi[3], Sabine Wurmehl[1,4], Bernd Büchner[1,4], Brian Peters[5], Fengyuan Yang[5], and Hitoshi Ohta[2,3] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, IFW Dresden, D-01171 Dresden, Germany — [2]Molecular Photoscience Research Center, Kobe University, Kobe 657-8501, Japan — [3]Graduate School of Science, Kobe University, 1-1 Rokkodai-cho, Nada, Kobe 657-8501, Japan — [4]Institut fur Festkörperphysik, Technische Universität Dresden, D-01062 Dresden, Germany — [5]Department of Physics, The Ohio State University, Columbus, Ohio 43210, USA

Heusler alloys have attracted a considerable attention in recent years since they are predicted to be halfmetallic ferromagnets. Possible 100% spin polarization of their conduction electrons together with high magnetic moments and high values of the Curie temperature give them a significant potential for spintronics applications. In order to create a fast switching and thermally stable spintronic device one should be able to control a magneto-crystalline anisotropy and a Gilbert damping of the used material. One of the most informative experimental methods to study magneto-crystalline anisotropy and Gilbert damping is frequency tunable ferromagnetic resonance (FMR). In this work we present a first study of magneto-crystalline anisotropy and Gilbert damping using a unique high frequency FMR technique where the response is detected by the micro-cantilever.

MA 17.64 Tue 9:30 Poster B1

Understanding the ordering phenomena in $Co_2FeAl_{0.5}Si_{0.5}$ through *in situ* neutron diffraction — •Ahmad Omar[1], Matthias Frontzek[2], Alexey Alfonsov[1], Bernd Büchner[1,3], and Sabine Wurmehl[1,3] — [1]IFW Dresden, 01069, Germany — [2]Paul Scherrer Institute, 5232 Villigen, Switzerland — [3]Institut für Festkörperphysik, TU Dresden, 01062, Germany

The $Co_2FeAl_{0.5}Si_{0.5}$ Heusler compound is predicted to be a half-metallic ferromagnet in the ordered $L2_1$ structure but it is difficult to obtain a pure $L2_1$ order due to anti-site disorder. Hence, 100% spin polarization has not been observed in general. Therefore, it is important to understand the ordering phenomena with temperature in the material so as to optimize the ordering post-synthesis. We present *in situ* neutron diffraction measurements performed during high temperature annealing of powder samples along with powder neutron diffraction at room temperature on pre-annealed polycrystalline samples in order to compare the effect of various annealing procedures. We show that the annealing procedures commonly followed in literature do not offer significantly large improvement in the $L2_1$ order. A sharp $L2_1$-B2 ordering transition is not observed, in contrast to what is commonly understood. We also discuss the ordering phenomena in the light of existence and evolution of antiphase domains and domain boundaries though detailed line profile analysis of the neutron diffraction data. Based on our understanding, we have been able to optimize the annealing procedure. A higher $L2_1$ ordering, as compared to conventional annealing, has been obtained which was confirmed using zero-field NMR measurements.

MA 17.65 Tue 9:30 Poster B1

$Mn_{3+x}Ge$ Heusler compound with perpendicular magnetic anisotropy — •Hendrik Dohmeier, Alessia Niesen, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

New magnetic materials have to be prepared and characterized in order to build future spintronic devices like the spin-transfer-torque-(STT)-MRAM. Materials with a large perpendicular magnetic anisotropy are good candidates for this kind of devices. Mn_3Ge is a promising material due to the tetragonally distorted $D0_{22}$ crystal structure. An intrinsic characteristic of this tetragonal Heusler alloy is the uniaxial magnetic anisotropy with an out-of-plane oriented magnetic easy axis.[1] For this reason $Mn_{3+x}Ge$ thin films were prepared by dc magnetron co-sputtering on MgO (001) and $SrTiO_3$ (001) substrates to promote (001)-oriented films. Since crystalline quality and surface roughness dependend on the deposition temperature and stoichiometric composition, different parameters were tested to reduce roughness and suppress the creation of secondary crystal phases. Crystallographic and magnetic properties were investigated via x-ray diffraction (XRD), anomalous Hall effect (AHE) and magneto-optic Kerr effect (MOKE). The surface roughness was verified via x-ray reflection (XRR). XRD measurements verified the $D0_{22}$ crystal structure with an out-of-plane lattice constant of c = 7.21 Å, while MOKE and AHE measurements confirmed a magnetic out-of-plane anisotropy.

[1] H. Kurt et al., Appl. Phys. Lett. 101 (2012) 132410

MA 17.66 Tue 9:30 Poster B1

Search for magnetocaloric materials in the Co-Mn-Si system — •Franziska Seifert, Christian G.F. Blum, Bruno Weise, Anja Waske, Martin Knupfer, Bernd Büchner, and Sabine Wurmehl — Leibniz Institute for Solid State and Materials Research

Materials, which show a large magnetocaloric effect are interesting for modern cooling systems. One way to obtain a particularly large effect is by means of a magnetic phase transition. Some materials show a meta-magnetic transition (e.g. antiferromagnetic to ferromagnetic) with related large entropy changes. In this study we were able to find such a meta-magnetic transition in the Co-Mn-Si system. For this aim we prepared a sample series $Co_{2-x}Mn_{1+x}Si$ between the ferromagnetic Co_2MnSi and the antiferromagnetic Mn_3Si parent compound by changing the Co-Mn ratio. In some samples the MnCoSi phase is present, which might play an important role for structural and magnetic properties in that series.

MA 17.67 Tue 9:30 Poster B1

Growth & structural characterization of magnetically coupled trilayer systems Fe/x/Gd (x=Mn,Sc) — •Samira Webers[1], P. Anil Kumar[1], Dirk Walecki[1], Biplab Sanyal[2], Carmine Autieri[2], Mark Gubbins[3], and Heiko Wende[1] — [1]Faculty of Physics and Center of Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Germany — [2]Department of Physics and Astronomy, Uppsala University, Sweden — [3]Seagate, Northern Ireland

As predicted by theory, we show that it is possible to produce ferromagnetically coupled layers of Fe and Gd via an antiferromagnetic or non-magnetic intermediate layer like Sc or Mn. These studies build on our earlier investigation of the Fe/Cr/Gd system [1]. We are able to grow these trilayer systems by molecular beam epitaxy on GaAs(100) substrates. It has been found that by modification of the spacer layer thickness, we obtain a larger net magnetic moment for this system. As determined by magnetometry measurements, it is necessary to grow flat and well defined monolayers. For this reason, the growth characterization is crucial. We use *in situ* Reflection High Energy Electron Diffraction to investigate the layer growth and to crosscheck the thickness calibration.

[1] F. Stromberg et al., *Textured growth of the high moment material Gd(0001)/ Cr(001)/ Fe(001)*, J. Phys D: Appl. Phys. 44, 265004 (2011)

MA 17.68 Tue 9:30 Poster B1

Perpendicular CoFeB-based magnetic tunnel junctions with exchange bias — •Orestis Manos, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

This study investigates CoFeB-based magnetic tunnel junctions with perpendicular magnitized electrodes (pMTJs) combing exchange bias (EB). The magnetically soft electode is on top of the sample, consting of SiO_2/Mo(5)/MgO(1.8)/Co-Fe-B(1)/Mo(5) in (nm). The pinned bottom electrode is formed as SiO_2/Ta(10)/Ru(30)/Ta(5)/A(20)/X(10)/Co-Fe-B(1.2)/MgO(1.8) in (nm) where A=Pt, Ru and X=FeMn, IrMn [1]. In the aforementioned samples, the EB effect is observed as a shift of the magnetic hysteresis loop away from zero field, accompanied by an increase in coercivity. The phenomenon is related to the exchange interface interactions between the ferromagnet (FM) and the antiferromagnet (AFM). The crystallographic growth of the AFM affects critically the strength of the EB. The first aim is to change the growth direction of the FeMn/IrMn (111) from in-plane to perpendicular to the sample plane. The EB films were ex-situ post-annealed at several temperatures and their crystallograpic properties were investigated by X-ray diffraction (XRD). A [111] growth direction obtained for all seed layers. The samples with FeMn and IrMn combining Pt as a seed layer showed a perpendicular exchange bias field of 100 and 250 Oe, respectively.

[1] F. Garcia et al., J. Appl. Phys. 91, 6905 (2002)

MA 17.69 Tue 9:30 Poster B1

Quantitative analysis of the influence of keV Helium ion bombardment on the angular dependence of exchange bias — •Nicolas David Müglich[1], Markus Meyl[1], Alexander Gaul[1], Gerhard Götz[2], Günter Reiss[2], Timo Kuschel[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, Kassel D-34132, Germany — [2]Physics Department, Center for Spinelectronic Materials and Devices, Bielefeld University, Universitätsstraße 25, 33501 Bielefeld, Germany

Ion bombardment induced magnetic patterning (IBMP)[1] is a powerful tool for designing artificial magnetic field landscapes. During this process a number of material properties are modified due to the energy transferred by the ions into the magnetic layer system. Although IBMP is an established method; a quantitative description of these modifications is still missing.
In the present study, angular resolved hysteresis measurements in dependence of the Helium ion dose using vectorial Kerr magnetometry were performed. By comparing these results with calculations based on a Stoner-Wohlfarth-like model, a quantitative analysis of the modifications of the magnetic properties is given. Additionally the influence of magnetic patterning on the angular resolved dependence of the exchange bias is shown.
[1] A. Ehresmann, I. Krug, A. Kronenberger, A. Ehlers and D. Engel: Journal of Magnetism and Magnetic Materials 280 (2004) 369-376

MA 17.70 Tue 9:30 Poster B1

Optimal doping of antiferromagnetic MnN for improved exchange bias — •Mareike Dunz, Björn Büker, and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

In many spinelectronic devices, an exchange bias system is used to pin a ferromagnetic reference layer by coupling it to an antiferromagnetic film. We report on a new polycrystalline exchange bias system consisting of MnN/CoFe bilayers that shows high exchange bias of up to 1800 Oe at room temperature. However, it has a broad blocking temperature distribution with its median around 160 °C and requires larger film thicknesses of the antiferromagnetic MnN compared to other exchange bias systems [1].

To optimize the system, doping of the MnN layer was investigated. Defect energies of elements throughout the periodic table substituting Mn were calculated by density functional theory to find optimal dopants. Exchange bias stacks with doping concentrations of a few percent were prepared by reactive co-sputtering and their magnetic properties were analyzed. Effects of the defect energy, large atomic number, or large atomic radii are discussed.

[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 17.71 Tue 9:30 Poster B1

Non-collinear magnet U2Pd2In in applied magnetic field — •Leonid Sandratskii — Max Planck Institute of Microstructure Physics, Halle

The Uranium ternary compound U2Pd2In possesses an unusual ground-state magnetic structure with magnetic moments of the U atoms strictly orthogonal to each other. We report the analysis of the magnetic interactions in the U2Pd2In combining the first-principles calculations for non-collinear relativistic systems with symmetry analysis. Also, the self-consistent calculations are performed for U2Pd2In in an applied magnetic field of different strength. The theoretical results are compared with the results of recent experiments in strong magnetic fields.

MA 17.72 Tue 9:30 Poster B1

Cantilever Magnetometry on MnSi — •Matthias Dodenhöft[1], Schorsch Michael Sauther[1], Stephan Gerhard Albert[1], Felix Rucker[2], Andreas Bauer[2], Marc Andreas Wilde[1], Christian Pfleiderer[1,2], and Dirk Grundler[1,3] — [1]Phys.-Dep. E10, TU München — [2]Phys.-Dep. E51, TU München — [3]LMGN, IMX, STI, EPF Lausanne

Since the discovery of the Skyrmion lattice phase in 2009, the B20 compound MnSi has attracted much attention. However, a detailed experimental investigation of the Fermi Surface (FS) of bulk MnSi is still missing in literature. Existing density functional theory (DFT) band structure calculations are restricted by the strong electronic correlations present in MnSi. Therefore, a verification of the predicted FS by experiments is essential. Following a short report by Taillefer et al. (1986), we present de Haas-van Alphen (dHvA) measurements using cantilever magnetometry with a capacitive read-out. The Dingle temperatures extracted from experiment confirm an excellent sample quality enabling a detailed determination of the FS via the dHvA effect. Extracted frequency components of the dHvA signal are tracked for different field orientations in the (100), (110) and (211) plane and their evolution is compared with DFT results. Measurements for a fixed field orientation at different temperatures enable the determination of the effective mass of the orbits corresponding to each frequency component. We find effective masses that are strongly enhanced if compared to the bare band masses. We attribute this to electronic correlations not considered by DFT.

MA 17.73 Tue 9:30 Poster B1

Magnetic anisotropy and reduced neodymium magnetic moments in $Nd_3Ru_4Al_{12}$ — •D. Gorbunov[1], M. Henriques[2], A.V. Andreev[2], V. Eigner[2], A. Gukasov[3], X. Fabrèges[3], Y. Skourski[1], V. Petříček[2], and J. Wosnitza[1] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic — [3]Laboratoire Léon Brillouin, CE de Saclay, Gif-sur-Yvette, France

The present study addresses the magnetic properties of $Nd_3Ru_4Al_{12}$ (hexagonal crystal structure) with focus on its magnetic anisotropy that allows a comparison between single-ion and two-ion mechanisms when comparing to $U_3Ru_4Al_{12}$. $Nd_3Ru_4Al_{12}$ is a strongly anisotropic uniaxial ferromagnet with a Curie temperature of 39 K. The magnetic moments are aligned collinearly along the [001] axis. The magnetic structure has orthorhombic symmetry for which the crystallographic Nd site is split into two magnetically inequivalent positions, Nd1 and Nd2. The Nd1 and Nd2 atoms exhibit reduced magnetic moments, 0.95 and 2.66 μ_B, as compared to the free Nd^{3+}-ion value (3.28 μ_B). We argue this being due to crystal-field effects and competing exchange and anisotropy interactions. Since the single-ion mechanism in $Nd_3Ru_4Al_{12}$ leads to uniaxial anisotropy and the two-ion mechanism of the actinide analog, $U_3Ru_4Al_{12}$, is known to lead to planar anisotropy, our study demonstrates the decisive influence of these different mechanisms on the magnetic anisotropy.

MA 17.74 Tue 9:30 Poster B1

Magnetic properties of the chain antiferromagnets $RbFeSe_2$, $TlFeX_2$ (X=S,Se), and $Tl_3Fe_2S_4$ — •Zakir Seidov[1,2], Vladimir Tsurkan[1,3], Hans-Albrecht Krug von Nidda[1], Irina Filipov[3], Axel Günther[1], Arzu Najafov[2], Rushana Eremina[4], Tatyana Gavrilova[4], Airat Kiiamov[5], Farit Vagizov[5], Lenar Tagirov[5], and Alois Loidl[1] — [1]EP V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany — [2]Institute of Physics, Azerbaijan Academy of Sciences, AZ- 1143 Baku, Azerbaijan — [3]Institute of Applied Physics, Academy of Sciences of Moldova, MD-20208 Chisinau, Moldova — [4]E.K.Zavoisky Physical Technical Institute, Russian Academy of Sciences, 420029 Kazan — [5]Institute of Physics, Kazan Federal University, Kazan 420008, Russia

The ternary iron chalcogenides, monoclinic $TlFeS_2$, $TlFeSe_2$, $RbFeSe_2$ consisting of linear chains of tetrahedra, and orthorhombic $Tl_3Fe_2S_4$ with zigzag chains of tetrahedra have been investigated by means of magnetic susceptibility, specific heat, Mössbauer, and ESR measurements. Single crystals of $TlFeS_2$, $TlFeSe_2$, $RbFeSe_2$, and $Tl_3Fe_2S_4$ exhibit three-dimensional collinear antiferromagnetic order with strongly reduced moments below 196K, 290K, 248K, and 90K, respectively. The magnetic moments are oriented perpendicular to the chain direction. $Tl_3Fe_2S_4$ reveals a susceptibility maximum at $T_{\max} = 435$K, which is typical for one-dimensional antiferromagnetic spin chains, whereas $RbFeSe_2$ and $TlFeX_2$ (X = S, Se) exhibit a continuous linear increase of the susceptibility up to the highest measurement temperature (600K) suggesting 1D metallic character.

MA 17.75 Tue 9:30 Poster B1

Excitonic condensation in d^6 perovskites — •Juan Fernández Afonso[1] and Jan Kuneš[2] — [1]Institute of Physics of the Czech Academy of Sciences — [2]Institute of Physics of the Czech Academy of Sciences

We study the possibility of excitonic condensation in transition metal perovskites with d^6 configuration. Hartree-Fock-like LDA+U calculations have been performed for artificial cubic perovskite structure mimicking $LaCoO_3$. We find self-consistent solutions that correspond to several distinct ordered states. These arise from condensation of atomic size $e_g - t_{2g}$ excitons and lead to periodic arrangement of magnetic multipoles. The symmetry properties and stability of the different solutions are analyzed.

MA 17.76 Tue 9:30 Poster B1

ESR studies of the $S = 1/2$ Heisenberg chain compound $Cu(py)_2Cl_2$ — •A.N. Ponomaryov[1], J. Wosnitza[1], K.Yu. Povarov[2], M. Thede[2], A. Zheludev[2], E. Ressouche[3], and S.A. Zvyagin[1] — [1]High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Neutron Scattering and Magnetism, Laboratory for Solid State Physics, ETH Zürich, Switzerland — [3]INAC SPSMS, CEA and Université Joseph Fourier, F-38000 Grenoble, France

$Cu(NC_2H_5)_2Cl_2$, a $S = 1/2$ Heisenberg chain compound with exchange interaction $J = 13.4$ K, was studied by means of electron paramagnetic resonance spectroscopy. A single resonance line was observed in the temperature range from 2 to 300 K. The angular dependence of the resonance absorption indicates the presence of two magnetic centers, which is in agreement with the crystallographic structure. The temperature dependence of the resonance linewidth line was analyzed by use of the Oshikawa and Affleck theory (Phys. Rev. B, 65, 134410). The corresponding spin-Hamiltonian parameters were extracted and analyzed.

This work was partly supported by the DFG.

MA 17.77 Tue 9:30 Poster B1

Study of candidate compounds for magnetocaloric materials in the system Mn2-xMxSb (M=Fe, Co) — •Mamuka Chikovani, Karen Friese, Paul Hering, Jörg Voigt, Jörg Persson, and Thomas Brückel — JCNS-2/PGI 4, Forschungszentrum Jülich GmbH, Germany

Magnetocaloric refrigeration is an emerging technology in today*s cooling devices and it has a potential to save about 20-30 % of energy compared to conventional vapor compression technology. Nowadays, the most important issue is to find cheap and abundant materials exhibiting a sizable magnetocaloric effect. We report on preparation and characterization of compounds of general composition * Mn2-xMxSb system with M = (Fe, Co). The substitution on the Mn site has an effect on magnetic properties and magnetic transitions. We synthesized samples of different stoichiometry by inductive melting of the elements in a cold crucible and performed studies using x-ray powder diffraction method and macroscopic magnetization measurements. Based on these data we could then calculate the entropy change. In the Fe-containing samples, in particular in Mn1.8Fe0.2Sb, we observe a small MCE associated to a paramagentic-ferrimagnetic phase transition. The Co-doped samples reveal a sizeable MCE accompanying a ferri-to-antiferromagnetic phase transition. Currently we study the response of the lattice parameter to the magnetic transitions with low temperature powder diffraction (300-15 K).

MA 17.78 Tue 9:30 Poster B1

Magneto-optical effects in $L_{10} - Mn_xGa$ films with giant perpendicular anisotropy — •Liane Brandt[1], Lijun Zhu[1], Jianhua Zhao[2], and Georg Woltersdorf[1] — [1]Institute of Physics, Martin-Luther-University Halle-Wittenberg, von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]State Key Laboratory of Superlattices and Microstructures, Institute of Semiconductors, Chinese Academy of Sciences, P. O. Box 912, Beijing 100083, China

We report very large polar magneto-optical effects in metallic $L_{10} - Mn_xGa$ (0.76 ≤ x ≤ 1.5) epitaxial films with giant perpendicular magnetic anisotropy ($K_u \sim 1\ MJ/m^3$). Both the Kerr rotation and ellipticity show a strong dependence on the sample composition most likely caused by a variation of spin-orbit coupling strength and strain. A Kerr rotation of up to 0.1 degrees is observed for a 40 nm thick film for a wavelength of 650 nm at room temperature. The large polar Kerr effect, the high reflectivity, and the giant magnetic anisotropy make $L_{10} - Mn_xGa$ a promising material for high frequency spintronic and magneto-optic applications.

MA 17.79 Tue 9:30 Poster B1

Single crystal growth and magnetic anisotropy of transition metal substituted Li_3N — •Manuel Fix[1], Stephan 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]. Moreover, dilute Fe-substitution in Li_3N leads to a quantum tunnelling of the magnetization similar to single-molecule magnets [2].

Here we show the growth of single crystals of Fe- and Ni-substituted Li_3N via a flux method. Single crystals of several millimetres along a side could be obtained. The samples were characterized structurally by powder X-Ray diffraction and Laue back-reflection and chemical analysis was performed via ICP-OES. To prevent degradation of the extremely air-sensitive samples, the growth as well as the characterization were performed under inert atmosphere. We present the magnetic properties obtained by measurements of isothermal and temperature-dependent AC and DC magnetization. Furthermore, the influence of a static external magnetic field on the quantum tunnelling of the magnetization and on thermally activated relaxation processes in $Li_2(Li_{1-x}Fe_x)N$ is discussed.

[1] A. Jesche *et al.*, Phys. Rev. B **91**, 180403(R) (2015)
[2] A. Jesche *et al.*, Nature Comm. **5**:3333 (2014)

MA 17.80 Tue 9:30 Poster B1

Structural and magnetic properties of Fe-Ce-W (12:1 and 29:3) intermetallic compounds — •Roman Karimi, Dagmar Goll, Ralf Loeffler, Roland Stein, and Gerhard Schneider — Materials Research Institute (IMFAA), Aalen University, Germany

For low-cost permanent magnet applications Ce-based hard magnetic intermetallic compounds are currently in the focus of research due to the better abundance of Ce in the earth crust compared to Nd or Dy. By bulk high-throughput experimentation based on heterogeneous non-equilibrium states the two hard magnetic compounds $Fe_{11}WCe$ (12:1 phase stronger magnetic) and $Fe_{29-x}W_xCe_3$ (29:3 phase, weaker magnetic) have been discovered in the ternary system Fe-Ce-W. As $Fe_{11}WCe$ looks very promising for novel permanent magnets single-phase material has been fabricated by arc-melting. The samples have been analyzed concerning their crystallographic structure and intrinsic magnetic properties using x-ray diffraction, domain pattern analysis and magnetometry. The lattice structure has been identified as $ThMn_{12}$ structure. For the intrinsic properties saturation polarization J_s, anisotropy constant K_1 and Curie temperature T_C values of J_s(RT) ∼ 1.1 T, K_1(RT) ∼ 2 MJ/m^3 and T_C ∼ 450 K were found for the 12:1 compound. Values of J_s(RT) ∼ 0.5 T and K_1(RT) ∼ 0.5 MJ/m^3 have been estimated for the 29:3 compound. Mechanical alloying is applied to realize nanocrystalline $Fe_{11}WCe$ magnets. Project supported by BMBF (project REleaMag) and Carl-Zeiss-Stiftung.

MA 17.81 Tue 9:30 Poster B1

Growth and characterization of β-Mn-type $Co_8Zn_8Mn_{4-x}Fe_x$ polycrystals — •Kai Dietze, Justus Christinck, Nico Steinki, Stefan Süllow, and Dirk Menzel — Institut für Physik der Kondensierten Materie, Technische Universität Braunschweig, Mendelssohnstr. 3, 38106 Braunschweig, Germany

In the ongoing research in spintronics, materials hosting magnetic skyrmions are getting more and more interesting due to the possible use of data storage and processing abilities. Generally, skyrmions are present in the magnetically ordered phase close to the ordering temperature far beneath 300 K. On the basis of their lacking inversion symmetry, some substitutes of β-Mn-type $Co_{10}Zn_{10}$ show promising characteristics for skyrmions above room-temperature. Lorentz transmission electron microscopy has indicated the presence of skyrmions in $Co_8Zn_8Mn_4$ around 345 K [1]. In our studies we focus on the crystal growth of $Co_8Zn_8Mn_{4-x}Fe_x$ samples and have performed a basic characterization. X-ray powder diffraction in combination with Rietveld-analysis confirms the β-Mn structure. SQUID magnetization and elevated-temperature resistivity measurements were performed in order to obtain information about the electronic and magnetic structure and specify the degree of purity.

[1] Y. Tokunaga et al., Nat. Commun. **6**, 7638 (2015).

MA 17.82 Tue 9:30 Poster B1

Coercivity Enhancement of Nd-Fe-B Permanent Magnets by Grain Boundary Diffusion — •Konrad Loewe, Tim Lienig, Dimitri Benke, and Oliver Gutfleisch — TU Darmstadt, FB Materials Science, 64287 Darmstadt

A way to enhance the relatively poor temperature stability of coercivity of modern Nd-Fe-B-based sintered magnets is the substitution of Heavy Rare Earth (HRE) for Nd in the so-called '2-14-1'-structure of the magnetic main phase. This way the anisotropy field Ha increases, albeit at the expense of the saturation magnetization Ms and therefore the maximum storable energy. A possibility to overcome this drawback is to concentrate the HRE only at the features of the microstructure where demagnetization is starting (so-called 'weak links'), i.e. the grain boundaries. In technical practice, the HRE are deposited on the surface of the finished magnets and diffuse into the volume during a heat treatment.

In the present work, it is shown that the diffusion of HRE mainly occurs over the grain boundaries leading to a distinct two phase microstructure consisting of HRE-lean grain cores surrounded by HRE-rich grain boundary areas. On the macroscopic scale the so obtained coercivity enhancement is decreasing with diffusion distance, leading to magnets with gradient properties over the range of several mm. The geometry dependent optimum distribution of coercivity is predicted with FEM simulations and correlated with experimental data.

MA 17.83 Tue 9:30 Poster B1

Magnetic properties of off-stoichiometric Mn-Bi single- and poly-crystals — •Semih Ener[1], Yu-Chun Chen[2], Konstantin P. Skokov[1], Helmut Kronmüller[2], Eberhard Goering[2], and Oliver Gutfleisch[1] — [1]Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany — [2]Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart, Germany

Current permanent magnet market is dominated by the high-performance Nd-Fe-B and low-cost hard-ferrite magnets. The rare-earth crisis in 2011 led researchers to focus on two main research topics: i) optimized usage of the rare-earths and ii) developing new hard magnetic materials. The low-temperature-phase (LTP-) MnBi is a promising candidate as a hard magnetic material due to its high theoretical magneto-crystalline anisotropy and positive β coefficient. In this study the single- and poly-crystals of off-stoichiometric Mn-Bi samples are presented. The optimum secondary phase (pure-Bi) concentration in the bulk samples is discussed for achieving reasonable coercivity and remanence values for the final product. The room temperature x-ray diffraction patterns show the LTP-MnBi phase as a main phase and secondary phase of pure-Bi for almost all investigated samples. Magnetic measurements show the possibility to tune the magnetic properties in a wide variety of coercive field and remanence values up to 1.75 T and 0.7 T, respectively. The authors gratefully acknowledge the support of the Deutsche Forschungsgemeinschaft for the project HPPMSNG.

MA 17.84 Tue 9:30 Poster B1

Room temperature ferromagnetism in graphite oxide nanoplatelets induced by Na-islands defects — •Katherine Gross[1], Jhon J. Prias[2,3], Hernando Ariza[2], and Pedro Prieto[1] — [1]CENM, Universidad del Valle, Colombia — [2]IIS, Universidad del Quindío, Colombia — [3]EITP, Universidad del Quindío, Colombia

We have studied the magnetic response of pyrolytic graphite oxide nanoplatelets (GONP) extracted from bamboo pyroligneous acid (BPA) by systematically varying the crystal structure and topological defects. The crystal structure of the samples as well as the surface topography is modified by increasing the carbonization temperature in a range from 473K to 973K. At 973K a higher ordered crystalline graphite structure is obtained. M vs. H measurements of GONP-BPA samples show ferromagnetic (FM) order at room temperature. Magnetic force microscopy gives direct evidence for local FM order at the topological defects. Magnetic properties are correlated with the presence of topological defects caused by a natural formation of Na-islands during the carbonization process, which modify considerably the topography of the nanoplatelets. Our overall results discard any correlation of the FM order with the presence of magnetic impurities.

MA 17.85 Tue 9:30 Poster B1

Electrochemical Properties and Valence Tuning of Li-Metal-Nitrides — •Elisa Thauer[1], Michael Richter[1], Alexander Ottmann[1], Christoph Neef[1], Manuel Fix[2], Anton Jesche[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, D-69120 Heidelberg, Germany. — [2]Experimentalphysik VI, Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany.

Lithium nitrides $Li_2(Li_{1-x}M_x)N$ with M = Fe or Ni are studied regarding their potential as anode materials in lithium-ion batteries by means of cyclic voltammetry and galvanostatic cycling. In addition, based on these results, the lithium content and thus the valence of the metal ions is altered electrochemically and the effect on the magnetic properties is studied by means of SQUID magnetometry.

MA 17.86 Tue 9:30 Poster B1

Magnetic moments and damping parameters of 4*d* and 5*d* transition metal doped FeCo alloys — •Rudra Banerjee, Carmine Autieri, and Biplab Sanyal — Uppsala University

FeCo alloys are very important for their high saturation magnetization and high Curie temperature, especially $Fe_{0.65}Co_{0.35}$ alloy that sits on the top of Slater-Pauling curve. However, there is a perpetual interest to achieve higher saturation moment. Also, for magnetic recording industry, materials with low damping parameters are sought for. Here we have done a systematic *first principles* study of FeCo alloys doped with 4*d* and 5*d* elements to study the magnetic behaviour of the systems. All the calculations have been done using density functional based Korringa-Kohn-Rostoker method with the configuration averaging described by coherent potential approximation. We report the saturation moments and Gilbert damping parameters for $Fe_{0.65}Co_{0.35-y}X_y$ and $Fe_{0.65}Co_{0.35-y-z}X_yX'_z$ system where X and X′ are 4*d* and 5*d* elements. We have found that 4d and 5d co-doped FeCo alloys posses magnetization and damping parameters suitable for applications.

MA 17.87 Tue 9:30 Poster B1

Synthesis and magnetic properties of $SrAl_2Fe_{10}O_{19}/\alpha''$-$Fe_{16}N_2$ nanocomposites — •Imants Dirba[1], Fabian Rhein[1,2], and Oliver Gutfleisch[1] — [1]Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany — [2]Siemens AG, Corporate Technology, 80200 Muenchen, Germany

Despite the superior magnetic properties of Nd-Fe-B, hard ferrites still dominate global permanent magnet market (in terms of tonnage) due to their low price combined with moderate magnetic performance. In this context, even a slight improvement in magnetic properties without significantly added cost would be of great importance. Here we report an attempt to increase the maximum energy product $(BH)_{max}$ of $SrAl_2Fe_{10}O_{19}$ hexaferrite by exchange-coupling on nanoscale with a phase with higher polarisation. Nanocomposites from $SrAl_2Fe_{10}O_{19}$ as a hard and α''-$Fe_{16}N_2$ as a soft (semihard) phase have been synthesized. Morphology, structural and magnetic properties have been investigated in order to optimize synthesis conditions and achieve exchange-coupling between both phases.

MA 17.88 Tue 9:30 Poster B1

Optical and magneto-optical spectroscopy of $Co_2FeGa_{0.5}Ge_{0.5}$ thin films — •Daniel Kral[1], Radek Jesko[2], Lukas Beran[1], Roman Antos[1], Martin Veis[1], Dominik Legut[2], Enrique Vilanova[3], Gerhard Jakob[3], and Jaroslav Hamrle[2] — [1]Institute of Physics, Charles University in Prague, Prague, Czech Republic — [2]Nanotechnology Centre, VSB-Technical University of Ostrava, Ostrava, Czech Republic — [3]Institute of Physics, University of Mainz, Mainz, Germany

Heusler compounds are well known as exceptionally tunable materials. They have received considerable attention due to their high Curie temperature and high spin polarization [1], which makes them good candidates for applications in novel spintronic devices.

In this work, we present a systematic study of optical and magneto-optical (MO) properties of $Co_2FeGa_{0.5}Ge_{0.5}$ Heusler compounds by means of spectroscopic ellipsometry and Kerr MO spectroscopy. The samples were grown by DC sputtering onto MgO/Al_2O_3 substrates under various conditions. MO Kerr spectroscopy was carried out in polar and longitudinal configurations in the photon energy range from 1.2 to 5 eV. The information about the spectral dependence of complete permittivity tensor of all samples was deduced form ellipsometric and MO measurements. Finally, all experimental data were confronted with ab-initio calculations.

This work was supported by Grant Agency of Czech Republic (grant no. 13-30397S).

[1] S. Wurmehl, et al., Appl. Phys. Lett. 88, 032503 (2006).

MA 17.89 Tue 9:30 Poster B1

Analysing the electronic behavior of $HoMn_2O_5$ with spectroscopic Ellipsometry — Paul J. Graham[1], •Bastian Besner[2], Gerd Neuber[2], Shirly J. Espinoza-Herrera[3], Michael A. Rübhausen[2], and Clemens Ulrich[1] — [1]School of Physics and School of Materials Science and Engineering, The University of New South Wales, Sydney, New South Wales 2052, Australia — [2]Institut für Nanostruktur- und Festkörperforschung, Center for Free-Electron Laser Science, Advanced Study Group APOG, University of Hamburg, Luruper Chaussee 149, 22761 D Hamburg, Germany — [3]ELI Beamlines Project, Institute of Physics of the ASCR, Na Slovance 2, 18221 Prague, Czech Republic

Spectroscopic ellipsometry is a reliable and accurate tool to measure the optical properties of various types of samples. To get a better scientific knowledge of the spin structure and magnetic frustration in multiferroics, it is necessary to measure the optical parameters of the samples at different temperatures. In this work, we present the optical properties of $HoMn_2O_5$ as a function of temperature measured with spectroscopic ellipsometry. To understand the incommensurate antiferromagnetic ordering below 40K, we measured at various temperatures ranging between 45K and 14K and sweeping the energy from 0.5 eV to 5 eV. The different behavior of the dielectric function in the different magnetic phases will be discussed. Furthermore we analyzed the anisotropic behavior of $HoMn_2O_5$ at room temperature and identified a 2-fold symmetry behavior of the pseudodielectric function.

MA 18: Topical session: Caloric Effects in ferroic materials I - Magnetocalorics

Time: Tuesday 10:15–11:45 Location: H53

MA 18.1 Tue 10:15 H53

The coupling of electronic, magnetic and lattice degrees of freedom in the magnetocaloric system La-Fe-Si — •Markus E. Gruner[1,2], Werner Keune[1], Beatriz Roldan Cuenya[3], Claudia Weis[1], Joachim Landers[1], Soma Salamon[1], Benedikt Eggert[1], Sergey I. Makarov[1], David Klar[1], Michael Y. Hu[4], Ercan E. Alp[4], Jiyong Zhao[4], Maria Krautz[5], Oliver Gutfleisch[6], and Heiko Wende[1] — [1]Universität Duisburg-Essen — [2]Forschungs-Neutronenquelle FRM II, Garching — [3]Ruhr-Universität Bochum — [4]Argonne National Laboratory — [5]IFW Dresden — [6]TU Darmstadt

$LaFe_{13-x}Si_x$ counts in its hydrogenated form as one of the most promising magnetocaloric materials for application. By combination of nuclear resonant inelastic X-ray scattering and first-principles calculations in the framework of density functional theory, we could recently demonstrate an unexpected phonon softening at the magnetic phase transition of pure La-Fe-Si, which contributes cooperatively with the magnetic degrees of freedom to the large magnetocaloric effect. The softening is traced back to adiabatic electron phonon coupling which originates from specific changes in the electronic density of states at the Fermi Level due to the itinerant electron metamagnetism of Fe [1]. Within this contribution we will review the signatures of itinerant electron metamagnetism and its implication for the magnetoelastic coupling in pure, Mn-doped and hydrogenated La-Fe-Si. Funding by the DFG (SPP1599, TRR80) is gratefully acknowledged.
[1] M. E. Gruner, W. Keune, B. Roldan Cuenya *et al.*, Phys. Rev. Lett. 114, 057202 (2015)

MA 18.2 Tue 10:45 H53

Element-resolved vibrational dynamics and thermodynamics of magnetocaloric FeRh compound — •Werner Keune[1], Markus E. Gruner[1], Joachim Landers[1], Soma Salamon[1], Franziska Scheibel[1], Detlef Spoddig[1], Beatriz Roldan Cuenya[2], Oliver Gutfleisch[3], Michael Y. Hu[4], Jiyong Zhao[4], Thomas Toellner[4], Ercan E. Alp[4], and Heiko Wende[1] — [1]Universität Duisburg-Essen, Germany — [2]Ruhr-Universität Bochum, Germany — [3]TU Darmstadt, Germany — [4]Argonne National Laboratory, USA

Employing both 57Fe nuclear resonant inelastic X-ray scattering and first principles calculations (DFT), similar to ref. [1], we determined the Fe-projected phonon DOS of the B2-ordered magnetocaloric FeRh compound at temperatures below and above the first-order magnetostructural phase transition from the antiferromagnetic (AFM) to the ferromagnetic (FM) state. Two experimental 57FeRh(001) thin-film samples on MgO(001) with different stoichiometries (AFM and FM, respectively) were studied. Distinct differences between the phonon DOS of the AFM and FM states were found. However, this leads only to very small differences in the T-dependences of the Fe-projected vibrational (lattice) specific heat C(T) and the vibrational entropy S(T), respectively, for the two magnetic states. The experimental Debye-Waller factor indicates that the lattice of the AFM state is softer than in the FM state.

[1] M. E. Gruner et al., Phys. Rev. Lett. 114, 057202 (2015).

MA 18.3 Tue 11:00 H53

Understanding the magnetostructural transitions of first-order materials — •Tino Gottschall, Dimitri Benke, Konstantin Skokov, Maximilian Fries, Iliya Radulov, and Oliver Gutfleisch — TU Darmstadt, Material Science, Darmstadt, Germany

The large magnetocaloric effect in the most promising first-order materials like La-Fe-Si [1], Fe2P type materials [2] or Heusler alloys [3] originates in the strong change of the magnetization with temperature being associated with a structural transformation. All these materials have one thing in common. The so-called magnetostructural transition goes hand in hand with a large volume change or at least a large change of the c to a ratio of the crystal structure.

In this work we present magnetic measurements of micrometer sized single particles of the three mentioned materials and compare them with the transformation characteristics of the corresponding bulk properties. It turns out that a very different behavior is observed depending on the size of the magnetocaloric sample. This result is of great importance for the application of magnetic refrigeration, especially for the design of powder bed heat exchangers.

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

[1] I.A. Radulov, K.P. Skokov, D.Yu. Karpenkov, T. Gottschall, O. Gutfleisch, J. Mag. Mag. Mater. 396 (2015) 228 [2] F. Guillou, H. Yibole, G. Porcari, L. Zhang, N.H. van Dijk, E. Brück, J. Appl. Phys. 116 (2014) 063903 [3] T. Gottschall, K.P. Skokov, B. Frincu, O. Gutfleisch, Appl. Phys. Lett. 106 (2015) 021901

MA 18.4 Tue 11:15 H53

Complex magnetic intermetallics and magnetocaloric effect — •Peter Entel1 — Faculty of Physics and CENIDE, University of Duisburg-Essen, 47048 Duisburg, Germany

We have performed ab initio electronic structure calculations and Monte Carlo simulations of magnetic intermetallics such as Fe-Al, Fe-Rh, Ni-Mn-Ga and Ni-Mn-(In, Sn) alloys. While Fe-Al shows mictomagnetic and metamagnetic features due to disorder and defects, near-stoichiometric Ni-Mn-Ga alloys show magnetic-field induced strain (MFIS), as the external magnetic field can drive the variant boundaries to move so that the magnetic easy axis is aligned parallel to the magnetic field direction. The other unusual type of ferroic shape-memory alloys like Ni-Mn-(In, Sn) (showing large magnetocaloric effects) leads to strongly frustrated magnetic behavior because of competing ferro- and antiferromagnetic interactions, where the parent phase shows considerably larger magnetization than the martensitic phase leading (in difference to Ni-Mn-Ga) to magnetic field-induced transformation (MFIT), namely a metamagnetic phase transition from martensite to austenite with increasing magnetic field. The related magnetostructural transiton leads to the kinetic arrest phenomenon at a critical temperature where the entropy difference between austenitic and martensitic phases and the driving force for further transformation vanish (which, alternatively has been assigned to a Kauzmann point). In addition, we find transitions to supercooled austenite and unfrozen strain glass and to a cluster-spin glass. We argue that this complexity originates from the ferroic frustration and noncollinear magnetism.

15 min. coffee break

MA 19: Magnetic Materials III

Time: Tuesday 11:30–13:15 Location: H31

MA 19.1 Tue 11:30 H31

Exchange interactions and Curie temperatures in tetrametal nitrides Cr4N, Mn4N, Fe4N, Co4N, and Ni4N — •Markus Meinert — Center for Spinelectronic Materials and Devices, Bielefeld University, Germany

The tetrametal nitrides exhibit a surprising relation between total magnetic moments, site-resolved magnetic moments and Curie temperatures. In Mn_4N, the Curie temperature is rather high, whereas the Curie temperatures of Fe_4N and Ni_4N are comparatively low.

Ab-initio calculations of the exchange interactions and classical Monte Carlo simulations of the temperature dependent magnetizations were performed to understand the observed relations. It turns out that the calculations reproduce the observed magnetic moments and Curie temperatures very well. The fact that the Curie temperature of Fe_4N is not higher than 760K in spite of the high magnetic moment (2.4 μ_B per Fe atom) can be traced back to an antiferromagnetic intra-sublattice interaction between Fe atoms on the unit cell faces, which destabilizes the ferromagnetic order.

MA 19.2 Tue 11:45 H31

First-principles investigation of the magnetic properties of $Fe_{1/4}NbSe_2$ — •H. Kouarta[1,2], J. Ibanez-Azpiroz[1], M. dos Santos Dias[1], S. Lounis[1], and H. Belkhir[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]Laboratoire d'Etudes des Surfaces et Interfaces du solide, Département de Physique, Faculté des Sciences, Université Badji Mokhtar, BP 12, 23000, Annaba, Algeria

We investigated from first-principles the intercalated transition metal dichalcogenide $Fe_{1/4}NbSe_2$ using the full-potential augmented plane waves and the Korringa-Kohn-Rostoker Green function methods. We explored the different possible magnetic states with a focus on the possibility to find Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions since the latter were proposed to occur in a similar material: $Fe_{1/4}TaS_2$[1]. The ground state is of antiferromagnetic nature, where the Fe spin magnetic moments were found to be smaller ($2.82\mu_B$) than the measured values ($4.9\mu_B$)[2]. Our analysis highlights the strong/weak hybridization between Fe 3d and Se 4p/Nb 4d states. Correlation effects in terms of an on-site Coulomb interaction U increased the moment by $\sim 0.5\ \mu_B$. With the spin-orbit interaction considered, an orbital moment of 0.6 μ_B was computed bringing the total Fe magnetic moment to 4 μ_B in a closer agreement with the experiment.

[1]K.-T.Ko et al., Phys. Rev. Lett, 107,247201 (2011); [2]S. S. P. Parkin and R. H. Friend, Philos. Mag. B 41, 65 (1980).

MA 19.3 Tue 12:00 H31

Magnetic anisotropy in MAX Phases — •Ruslan Salikhov[1], Ulf Wiedwald[1], Arni S. Ingason[2], Johanna Rosen[2], and Michael Farle[1] — [1]University Duisburg-Essen, Duisburg, Germany — [2]Linköping University, Linköping, Sweden

MAX phases (Mn+1AXn, where n = 1, 2, or 3) are ternary compounds consisting of an early transition metal M (including Mn), an A-group element A, and either C or N, denoted X. MAX phases have attracted considerable interest due to unique material properties combining properties usually associated with metals (electrically and thermally conductive) and ceramics (lightweight, stiff and resistive against oxidation) [1]. The crystal structure of MAX phases is hexagonal with repeated M-X-M (quasi 2D) atomic layers stacking in the c-direction with the A-element as a spacer. The recently discovered magnetic MAX phases (Cr0.5Mn0.5)2GaC and (Cr0.6Mn0.4)2GeC [2, 3] were prepared as epitaxial films and studied by ferromagnetic resonance (FMR) and SQUID magnetometry. We find that the (Cr0.5Mn0.5)2GaC film has a negligibly small magnetocrystalline anisotropy energy density (MAE) and the spectroscopic splitting factor is 2.00 +- 0.02 [4]. The (Cr0.6Mn0.4)2GeC film, however, shows a high MAE of 0.1 MJ/m3 at T = 100 K with the easy axis parallel to the c axis (perpendicular to the film plane).

[1] M. W. Barsoum, Prog. Solid State Chem. 28, 201, (2000).
[2] A. Petruhins et al., Journal of Materials Science 50, 4495 (2015).
[3] A. S. Ingason et al., Phys Rev Lett. 110, 195502 (2013).
[4] R. Salikhov et al., Mater. Res. Lett. 3, 156 (2015).

MA 19.4 Tue 12:15 H31

Resonant inelastic x-ray scattering of magnetic excitations in the novel 5d^4 iridate Ba_2YIrO_6 — •Maximilian Kusch[1], Tusharkanti Dey[1], Andrey Malyuk[1], Sabine Wurmehl[1], Bernd Büchner[1,2], Vamshi Katukuri[3], Beom Hyun Kim[5], Dmitry Efremov[3], Jeroen van den Brink[3], Marco Moretti[4], Michael Krisch[4], and Jochen Geck[1] — [1]Institute for Solid State and Materials Research, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden D-01062 Dresden, Germany — [3]Institute for Theoretical Solid State State Physics, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [4]European Synchrotron Radiation Facility, B.P.220, 38043 Grenoble, France — [5]Pohang university of science and technology

Ba_2YIrO_6 is a realization of a Ir-5d^4 electronic configuration forming a $J = 0$ ground state. Recently they gained particular interest since theoretical studies proposed, that a new type of van-Vleck like paramagnetism including excitation of non-zero J (J = 1, 2) might play an important role [khaliullin2013]. Our theoretical model calculations of the momentum dependence of these excitations predict a considerable dispersion of the J=1 and J=2 excitations and, in dependence on model parameters, a dramatic softening of excitations is observed. We performed high-resolution resonant inelastic x-ray scattering (RIXS) studies on Ba_2YIrO_6 to determine these dispersions experimentally. The results of these measurements are presented and discussed in comparison to the model calculations.

MA 19.5 Tue 12:30 H31

Interplay of structure and magnetism in frustrated intermetallic AFe_4X_2 systems — •Inga Kraft[1,2], Katharina Weber[1,2], Christoph Bergmann[1], Nandang Mufti[1], Til Goltz[2], Hans-Henning Klauss[2], Christoph Geibel[1], and Helge Rosner[1] — [1]Max Planck Intitute for Chemical Physics of Solids, Dresden — [2]Technical University of Dresden

Due to their complex and versatile behavior frustrated systems present a great experimental and theoretical challenges. Even slight perturbations induce instabilities in such systems and prompt the emergence of unusual phenomena. The intermetallic AFe_4X_2 compounds (A=Sc,Y,Lu,Zr; X=Si,Ge) are suggested to cover the whole regime from frustrated AFM order up to an AFM quantum critical point. Our DFT calculations exhibit a strong interplay of structure and magnetism. We discuss the influence of the A and X site atoms on the strength of magnetic interactions and the size of structural distortion.

MA 19.6 Tue 12:45 H31

Study of the magnetic excitation spectrum of the helimagnetic spinel compound $ZnCr_2Se_4$ — •Alistair Cameron[1], Yullia Tymoshenko[1], Yevhen Onykiienko[1], Pavlo Portnichenko[1], Helen Walker[2], Douglas Abernathy[3], and Dmytro Inosov[1] — [1]Institut für Festkörperphysik, TU Dresden, Germany — [2]ISIS Neutron Source, Rutherford Appleton Laboratory, United Kingdom — [3]SNS, Oak Ridge National Laboratory, United States

$ZnCr_2Se_4$ is a magnetoelectric compound with a cubic spinel ($Fd\bar{3}m$) structure. In zero applied field, the Cr^{3+} S=3/2 moments form an incommensurate magnetic ground state with a screw structure along the [100] direction and a T_N of 20 K, which transforms into a spin-spiral state in an applied magnetic field. Above the critical field H_{C2} this material exhibits a proposed spin-nematic state, before becoming fully ferromagnetic at H_{C3}. Previously, we studied this material with neutron diffraction, and found a temperature- and field-dependent magnetic structure in the spin-spiral phase with no long-range order in the proposed spin-nematic state. Here, we probe the spin-excitation spectrum of $ZnCr_2Se_4$ using time-of-flight neutron scattering, which allows us to investigate a large area of momentum space. The relatively short spin-spiral in $ZnCr_2Se_4$ leads to a large separation of the nuclear and magnetic Brag peaks in momentum space, making it possible to resolve excitations originating from a single magnetic Bragg peak. We observe two clear branches emanating from the magnetic satellites, an intense low energy mode alongside a steeper, less intense branch at higher energies.

MA 19.7 Tue 13:00 H31

Study of the geometrically frustrated compound $Nd_2Sn_2O_7$

— •Bertin A.[1], Dalmas de Réotier P.[2,3], Fåk B.[4], Marin C.[2,3], Yaouanc A.[2,3], Forget A.[5], Sheptyakov D.[6], Frick B.[4], Ritter C.[4], Amato A.[7], Baines C.[7], and King P.J.C.[8] — [1]TU Dresden — [2]Univ. Grenoble Alpes — [3]CEA-Grenoble, INAC-SPSMS — [4]Institut Laue-Langevin — [5]CEA-Saclay, Iramis, SPEC — [6]Paul Scherrer Institute, SINQ — [7]Paul Scherrer Institute, SμS — [8]ISIS Facility, Rutherford Appleton Laboratory

We have undertaken the study of the antiferromagnet pyrochlore compound $Nd_2Sn_2O_7$ where frustration lattice consists of magnetic ions sitting on a corner-shared tetrahedra network. This compound undergoes a second-order phase transition at $T_c = 0.91$ K into a non collinear "all-in-all-out" magnetic structure, confirmed by the presence of spontaneous oscillations resolved with zero-field μSR measurements. Persistent spin dynamics has been revealed through the temperature independent behaviour of the spin-lattice relaxation rate at low temperatures, and ascribed to 1-dimensional spin-loop excitations. This feature, together with the spin-wave-like excitations seen by specific heat measurements at low temperatures, are barely compatible with a purely Ising spin system and point to the existence of transverse exchange terms. Hence, the anisotropic Hamiltonian for dipolar-octupolar doublet will be discussed. Anomalously long paramagnetic fluctuations have also been revealed by μSR and neutron backscattering experiments up to $\approx 30\ T_c$. The funding of the current position of the presenting author by BMBF project 05K13ODA is acknowledged.

MA 20: Transport: Topological Insulators - 3D (Joint session of DS, HL, MA, O and TT organized by TT)

Time: Tuesday 14:00–15:45 Location: H18

Invited Talk MA 20.1 Tue 14:00 H18

Coupled-wire constructions: New insights into the physics of interacting topological systems in two and three dimension (and beyond)

— •Tobias Meng[1], Eran Sela[2], Titus Neupert[3], Martin Greiter[4], Ronny Thomale[4], Adolfo G. Grushin[5], Jens H. Bardarson[5], and Kirill Stengel[6] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel Aviv 69978, Israel — [3]Princeton Center for Theoretical Science, Princeton University, Princeton, New Jersey 08544, USA — [4]Institute for Theoretical Physics, University of Würzburg, 97074 Würzburg, Germany — [5]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany. — [6]Department of Physics & Astronomy, University of California, Riverside, California 92521, USA

Recently, it has been shown that coupled-wire constructions (CWCs) reproduce well-known fractional quantum Hall phases, and allow to derive new insights into, and setups for, interacting topological systems. I will review the basic concepts of 2D CWCs, discuss how they can teach us about spontaneous time-reversal symmetry breaking in topological insulators, and how they can be used to engineer chiral spin liquids in arrays of Mott-gapped quantum wires. I will show that 3D CWCs can for instance describe Weyl semimetals, and finally present new results on 4D fractional quantum Hall states built from coupled wires, whose 3D edges support a fractional chiral metal with a fractional chiral anomaly, thus generalizing the Weyl semimetal.

MA 20.2 Tue 14:30 H18

Revealing puddles of electrons and holes in compensated topological insulators

— •Nick Borgwardt[1], Jonathan Lux[2], Zhiwei Wang[1,3], Ignacio Vergara[1], Malte Langenbach[1], Achim Rosch[2], Yoichi Ando[1,3], Paul van Loosdrecht[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für theoretische Physik, Universität zu Köln — [3]Institute of Scientific and Industrial Research, Osaka University

Three-dimensional topological insulators harbour metallic surface states with exotic properties. In transport or optics, these properties are typically masked by defect-induced bulk carriers. Compensation of donors and acceptors reduces the carrier density, but the bulk resistivity remains disappointingly small. We show that measurements of the optical conductivity in $BiSbTeSe_2$ pinpoint the presence of electron-hole puddles in the bulk at low temperatures, which is essential for understanding DC bulk transport. The puddles arise from large fluctuations of the Coulomb potential of donors and acceptors, even in the case of full compensation. Surprisingly, the number of carriers appearing within puddles drops rapidly with increasing temperature and almost vanishes around 40 K. Monte Carlo simulations show that a highly non-linear screening effect arising from thermally activated carriers destroys the puddles at a temperature scale set by the Coulomb interaction between neighbouring dopants, explaining the experimental observation semi-quantitatively [1].

[1] N. Borgwardt et al., arXiv:1508.03212

MA 20.3 Tue 14:45 H18

Interaction Correction to the Magneto-Electric Polarizability of Z_2 Topological Insulators

— •Karin Everschor-Sitte[1], Matthias Sitte[1], and Allan MacDonald[2] — [1]Institut für Physik - Johannes Gutenberg-Universität Mainz, Deutschland — [2]Department of Physics - University of Texas at Austin, USA

When time-reversal symmetry is weakly broken and interactions are neglected, the surface of a Z_2 topological insulator supports a half-quantized Hall conductivity $\sigma_S = e^2/(2h)$. A surface Hall conductivity in an insulator is equivalent to a bulk magneto-electric polarizability, *i.e.* to a magnetic field dependent charge polarization. By performing an explicit calculation for the case in which the surface is approximated by a two-dimensional massive Dirac model and time-reversal symmetry is broken by weak ferromagnetism in the bulk, we demonstrate that there is a non-universal interaction correction to σ_S. Our prediction can be tested by measuring the capacitance of magnetized thin films in which the anomalous quantum Hall effect is absent.

MA 20.4 Tue 15:00 H18

Electron-Phonon Interaction in Surface States of Topological Insulators from First Principles

— •Rolf Heid[1], Irina Yu. Sklyadneva[2], and Eugine V. Chulkov[2] — [1]Institut für Festkörperphysik, Karlsruher Institut für Technologie — [2]Donostia International Physics Center (DICP), San Sebastian/Donostia, Spain

Transport through the metallic 2D surface states of 3D topological insulators with a Dirac-like dispersion is controlled by many-body interactions. In particular, a large electron-phonon interaction could be a limiting factor for applications at elevated temperatures [1]. Previous experimental investigations of the coupling constant remained inconclusive as they found large variations ranging from <0.1 to 3 [2].

Here we present a first principles investigation of the electron-phonon interaction in surface states of topological insulators within density-functional perturbation theory including spin-orbit interaction [3], using Bi_2Se_3, Bi_2Te_3, and Sb_2Te_2S as prominent examples. We discuss the various challenges faced by this approach, such as the rather deep penetration of the surface state and the small momentum range of both electronic and phonon states relevant for the coupling. We find that the coupling strength exhibits a significant dependence on the binding energy, following essentially the available electronic phase space. We further investigate the variation of the coupling with doping to mimic typical experimental conditions.

[1] D. Kim et al., PRL **109**, 166801 (2012)
[2] X. Zhu et al., arXiv: 1307.4559
[3] R. Heid et al., PRB **81**, 174527 (2010)

MA 20.5 Tue 15:15 H18

Detection of current-induced spin polarization in $BiSbTeSe_2$ toplogical insulator

— •Fan Yang[1], Subhamoy Ghatak[1], Alexey Taskin[1], Yuichiro Ando[2], and Yoichi Ando[1] — [1]Institute of Physics II, University of Cologne, Germany — [2]Department of Electronic Science and Engineering, Kyoto University, Japan

Topological insulators (TIs) are a class of quantum matter which possess spin-momentum-locked Dirac Fermions on the surfaces. Due to the spin-momentum locking, spin polarization will be induced when a charge current flows through the surface of a TI. Such spin polarization can be detected by using a ferromagnetic tunneling contact as a detector. In this talk, we present our results measured in devices

fabricated from $BiSbTeSe_2$ flakes. Spin signals were observed in both n-type and p-type $BiSbTeSe_2$ samples.

MA 20.6 Tue 15:30 H18

Transport measurements on epitaxial $Bi_{1-x}Sb_x$ thin films grown on Si(111) — •Julian Koch, Philipp Kröger, Herbert Pfnür, and Christoph Tegenkamp — Leibniz Universität Hannover, Inst. für Festkörperphysik, Appelstr. 2, 30167 Hannover

The alloy $Bi_{1-x}Sb_x$ can be tuned to be either topologically trivial or non-trivial by changing the relative concentrations of Bismuth and Antimony [1]. In this study we present surface transport measurements performed on non-trivial $Bi_{1-x}Sb_x$ films. Thin films grown by in-situ co-deposition on Si(111) substrates are used, in order to reduce bulk contributions and to provide the possibility of nanostructuring. The morphology was controlled by low energy electron diffraction. Temperature dependent transport measurements for temperatures from 12 to 300 K were performed for films of different stoichiometry ranging from $x = 0.14 - 0.22$ and thicknesses of 4, 8, 16 and 24 nm. We find strong evidence for metallic surface transport in addition to activated bulk transport, which is, to the best of our knowledge, the first observation of metallic surface transport in $Bi_{1-x}Sb_x$ films. In previous studies the transport findings were discussed solely in terms of impurity and bulk bands (see e.g. [2]). For films thinner than 6 nm the surface transport is strongly suppressed, in accordance with measurements on Bi_2Se_3 [3]. The temperature dependent transport behaviour of these films is similar to that of thicker films with substracted surface contribution as well as to films examined in previous studies, further supporting the observation of metallic surface transport in thicker films.

[1] H. Guo, K. Sugawara, A. Takayama, S. Souma, T. Sato, N. Satoh, A. Ohnishi, M. Kitaura, M. Sasaki, Q.-K. Xue, and T. Takahashi, PRB **83**, 201104(R)
[2] S. Cho, A. DiVenere, G. K. Wong, J. B. Ketterson, and J. R. Meyer, PRB **59** 10691
[3] A. A. Taskin, S. Sasaki, K. Segawa, and Y. Ando, PRL **109**, 066803

MA 21: Transport: Quantum Coherence and Quantum Information Systems - Theory 2 (Joint session of HL, MA and TT organized by TT)

Time: Tuesday 14:00–15:00 Location: H22

MA 21.1 Tue 14:00 H22

Emulating the 1-Dimensional Fermi-Hubbard Model with Superconducting Qubits — •Jan-Michael Reiner, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

A chain of qubits with both ZZ and XX couplings is described by a Hamiltonian which coincides with the Fermi-Hubbard model in one dimension. The qubit system can thus be used to study the quantum properties of this model. We investigate the specific implementation of such an analog quantum simulator by a chain of tunable Transmon qubits, where the ZZ interaction arises due to an inductive coupling and the XX interaction due to a capacitive coupling.

MA 21.2 Tue 14:15 H22

A method to efficiently simulate the thermodynamic properties of the Fermi-Hubbard model on a quantum computer — •Pierre-Luc Dallaire-Demers and Frank K. Wilhelm — Saarland University, Saarbrücken, Germany

Many phenomena of strongly correlated materials are encapsulated in the Fermi-Hubbard model whose thermodynamic properties can be computed from its grand canonical potential. In general, there is no closed form expression of the grand canonical potential for lattices of more than one spatial dimension, but solutions can be numerically approximated using cluster methods. To model long-range effects such as order parameters, a powerful method to compute the cluster's Green's function consists in finding its self-energy through a variational principle. This allows the possibility of studying various phase transitions at finite temperature in the Fermi-Hubbard model. However, a classical cluster solver quickly hits an exponential wall in the memory (or computation time) required to store the computation variables. Here it is shown theoretically that the cluster solver can be mapped to a subroutine on a quantum computer whose quantum memory usage scales linearly with the number of orbitals in the simulated cluster and the number of measurements scales quadratically. A quantum computer with a few tens of qubits could therefore simulate the thermodynamic properties of complex fermionic lattices inaccessible to classical supercomputers.

MA 21.3 Tue 14:30 H22

Scattering of photons on Bose-Hubbard lattices — •Kim Georg Lind Pedersen and Mikhail Pletyukhov — Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen

We study the photonic transport of weakly coherent light in various Bose-Hubbard lattice geometries implemented as QED cavity arrays. We use a diagrammatic scattering approach to study the relation between lattice geometry and the second order intensity correlation of the transmitted light. The motivation is twofold: First, a large induced correlation can be used to design circuit elements useful for "photonics applications". Second, the scattering of photons on complex lattices offers a promising way to characterize quantum correlation in a range of different, exotic states of matter theorized to be present in higher-dimensional cavity arrays.

MA 21.4 Tue 14:45 H22

Quantum Simulation of Hawking Radiation With Surface Acoustic Waves — •Raphael Schmit, Bruno G. Taketani, and Frank K. Wilhelm — Saarland University, Theoretical Physics Departement

In 1975, Hawking predicted particles and light to leave the surface of a black hole. This so called Hawking radiation follows the thermal spectrum of a black body with a certain temperature, called Hawking temperature. Its investigation is extremely desired since scientists believe it to provide clues for unanswered questions like the trans-Planckian problem or the information paradox, but a direct observation is challenging since the Hawking temperature is too small or the distance to the black hole is too large. For this purpose, we propose an experimental setup for emulating a black hole and measuring its analogue Hawking radiation. The setup consists of two adjacent piezoelectric semiconducting layers, one of them carrying a flying qubit serving as detector for Hawking radiation, and the other one with an attached MOS diode structure, imposing an effective curved metric on the surface acoustic wave (SAW) propagation. In the moving reference frame of the flying qubit, this metric matches the Painlevé-Gullstrand-metric describing an uncharged, non-rotating black hole with an event horizon for SAWs. We show that for GaAs as used layer material, the system can possess Hawking radiation in the μK regime. The flying qubit interacts with the Hawking phonons via piezoelectrically induced photons, and thus can be used to measure the temperature of the Hawking phonons.

MA 22: Magnetic Semiconductors (jointly with HL)

Time: Tuesday 14:00–15:15 Location: H31

MA 22.1 Tue 14:00 H31

Magnetic Semiconductor (Ga,Mn)As Studied by Fluctuation Spectroscopy — •Martin Lonsky[1], Jan Teschabai-Oglu[1], Klaus Pierz[2], Hans Werner Schumacher[2], and Jens Müller[1] — [1]Physikalisches Institut, Goethe-Universität, Frankfurt (M), Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

In spintronics, both charge and spin degrees of freedom of the electronic transport properties are utilized. Recent studies on diluted magnetic semiconductors (DMS), as for instance (Ga,Mn)As, raised hopes of applications combining the logic operations of semiconductor devices with the information storage capabilities of magnetic elements. However, ferromagnetism at room temperature has not yet been achieved in DMS, and the underlying mechanism is still subject of investigation. In this context, theoretical studies have discussed the percolation of magnetic polarons as a possible origin of spontaneous magnetization [1]. Motivated by recent results of a diverging $1/f$-noise magnitude in the ferromagnetic semimetal EuB_6, where the existence of percolating nanoscale magnetic clusters has been demonstrated [2], we apply fluctuation spectroscopy to (Ga,Mn)As in order to gain a better understanding of the coupling between charge transport and magnetism. Systematic (magneto-)transport studies are conducted on epitaxial thin films of (Ga,Mn)As [3] with different growth parameters.

[1] A. Kaminski and S. Das Sarma, Phys. Rev. Lett. 88, 247202 (2002)
[2] P. Das et al., Phys. Rev. B 86, 184425 (2012)
[3] A. B. Hamida et al., Phys. Stat. Solidi B 251, 1652 (2014)

MA 22.2 Tue 14:15 H31

Defect induced magnetism in SiC — •Shengqiang Zhou — Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany

Defect-induced magnetism is attracting intensive research interest. It not only challenges the traditional opinions about magnetism, but also has some potential applications in spin-electronics. SiC is a new candidate for the investigation of defect-induced ferromagnetism after graphitic materials and oxides due to its high material purity and crystalline quality [1, 2]. In this contribution, I will review our comprehensive investigation on the structural and magnetic properties of ion implanted and neutron irradiated SiC sample.

The magnetization in ion irradiated SiC can be decomposed into paramagnetic, superparamagnetic and ferromagnetic contributions [3,4]. The ferromagnetic contribution persists well above room temperature and exhibits a pronounced magnetic anisotropy. By combining X-ray magnetic circular dichroism and first-principles calculations, we clarify that p-electrons of the nearest-neighbor carbon atoms around divacancies are mainly responsible for the long-range ferromagnetic coupling [5]. Thus, we provide a correlation between the collective magnetic phenomena and the specific electrons/orbitals.

[1] APL 98, 222508 (2011); [2] PRB 90, 214435 (2014); [3] PRB 89, 014417 (2014); [4] PRB, 92, 174409 (2015); [5] Sci. Rep., 5, 8999 (2015).

MA 22.3 Tue 14:30 H31

Spin-lattice-relaxation of Bismut doped Silicons slabs in air - a DFT approach. — •Johannes Gugler and Peter Mohn — Center for Computational Materials Science, Vienna, Austria

ESR experiments show that Bismuth doped Silicon exhibits a relaxation-time up to 1 ms at 10 K. These huge values are obtained due to the electron-spin-free surrounding in a Silicon crystal. The absence of electron-spins makes spin-lattice-relaxation a process of interest, when it comes to quantum dots. We present a DFT-investigation of the crystalographic structure, the DOS, the phonon spectra and the configuration of Bismuth doped (100)- and (111)-Silicon surfaces in air. We evaluate the influence of different position of the Bismuth atom inside the silicon slab on the spin-lattice-relaxation mechanisms.

MA 22.4 Tue 14:45 H31

Interface control of electronic transport across the magnetic phase transition in SrRuO3/SrTiO3 heterointerface — •Carmine Autieri[1], Saurabh Roy[2], Biplab Sanyal[1], and Tamalika Banerjee[2] — [1]Department of Physics and Astronomy, Uppsala University, Box-516, 75120 Uppsala, Sweden — [2]Physics of Nanodevices, Zernike Institute for Advanced Materials, University of Groningen, Groningen 9747 AG,The Netherlands

The emerging material class of complex-oxides, where manipulation of physical properties lead to new functionalities at their heterointerfaces, is expected to open new frontiers in Spintronics. For example, SrRuO3 is a promising material where external stimuli like strain, temperature and structural distortions control the stability of electronic and magnetic states, across its magnetic phase transition, useful for Spintronics. Despite this, not much has been studied to understand such correlations in SrRuO3. Here we explore the influence of electron-lattice correlation to electron-transport, at interfaces between SrRuO3 and Nb:SrTiO3 across its ferromagnetic transition, using a nanoscale transport probe and first-principles calculations. We find that the geometrical reconstructions at the interface and hence modifications in electronic structures dominate the transmission across its ferromagnetic transition, eventually flipping the charge-transport length-scale in SrRuO3. This approach can be easily extended to other devices where competing ground states can lead to different functional properties across their heterointerfaces.

MA 22.5 Tue 15:00 H31

Transport effects in $LaCo_5$ and YCo_5 upon electronic topological phase transitions — •Jürgen Weischenberg and Hongbin Zhang — Materialwissenschaft, TU Darmstadt Alarich-Weiss-Straße 2, 64287 Darmstadt, Germany

It is an interesting phenomenon that in $RECo_5$ (RE = La, Y) strong pressure can lead to a Lifshitz transition, which is manifested by an isomorphic lattice collapse. As the lattice collapses and the distance between the atoms decreases, the overlap of their orbitals becomes larger and leads to an alteration of the Fermi surface topology, i.e., an electronic topological phase transition (ETT). Transport properties can be utilized to characterize the ETT, since they are determined by the details of the electronic structure at the Fermi energy level. In this work, to understand recent experiments in $LaCo_5$ [1], we carry out first principle calculations of various transport properties using the full-potential linearized augmented plane-wave method (FLAPW) within density functional theory. In particular, we consider both the intrinsic and the side-jump contribution to the anomalous Hall effect which can be computed directly from the electronic structure of the pristine crystal alone [2]. The impact of the Fermi surface topologies on the electric- as well as on the thermoelectric transport properties in $LaCo_5$ and YCo_5 is discussed. Financial support by German federal state of Hessen through its excellence program LOEWE RESPONSE is gratefully acknowledged.

[1] R. L. Stillwell *et al.*, Phys. Rev. B **92**, 174421 (2015)
[2] J. Weischenberg *et al.*, PRL 107, 106601 (2011)

MA 23: Magnetic Materials and Caloric Effects

Time: Tuesday 14:00–15:30 Location: H32

MA 23.1 Tue 14:00 H32

The influence of magnetocrystalline anisotropy on the magnetocaloric effect studied in Co_2B — •Maximilian Fries[1], Konstantin P. Skokov[1], Dmitriy Y. Karpenkov[1], Vicotrino Franco[2], Semih Ener[1], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt, Materialwissenschaft, Darmstadt, Germany — [2]Sevilla University, Dpto. Fisica de la Materia Condensata, Sevilla, Spain

Since the discovery of the magnetocaloric effect many promising material families like LaFeSi and Fe_2P-based alloys have been extensively studied. In addition, it has been found that especially the Fe_2P-type materials show large magnetocrystalline anisotropy which strongly influences the magnetocaloric properties. In order to quantify the influence of magnetocrystalline anisotropy on the magnetocaloric effect, we studied a single crystal of tetragonal Co_2B by means of magnetometry and adiabatic temperature change measurements. It is found that especially in fields smaller than 2 T the effect of anisotropy plays a significant role. In a field change of 1 T the MCE differs 50% from one to the other axis and 30% in 2 T in a temperature range bewteen 400 and 440K respectively. This behaviour will be explained by the rotational MCE. It is shown that especially in the aimed scenario of using magnetocaloric materials in rather small magnetic fields achievable by permanent magnets the effect of anisotropy needs to considered. We therefore propose utilizing textured non-cubic magnetocaloric materials with easy axis of magnetization parallel to the applied field in a device in order to increase the overall efficiency.

MA 23.2 Tue 14:15 H32

Magnetic phase transitions and their lattice responses in the compound system Mn5-xFexSi3 — •Paul Hering[1], Hang Zong[1], Ye Cheng[1], Karen Friese[1], Anatoliy Senyshyn[2], and Thomas Brückel[1] — [1]JCNS-2/PGI4, Forschungszentrum Jülich GmbH — [2]MLZ, TUM, Garching

Magnetic cooling based on the magnetocaloric effect could replace conventional vapor compression cooling, as it has a potentially lower energy consumption and does not rely on environmental hazardous gases. The compounds within the system Mn5-xFexSi3 undergo a variety of magnetic phase transitions at different temperatures depending on their iron content which is distributed on at least one mixed Mn/Fe site and one pure iron site [H. Binczyska, at al., Phys. Stat. Sol., Sect. A, 19, 13-17 (1973)]. The corresponding magnetic entropy changes show different shapes and magnitudes ranging from a negative MCE (x=0) to the modestly high positive magnetocaloric effect (MCE) of 2.9 J/kg K at a magnetic field change from 0 T to 2 T (x=4) [Songlin, et al., J. Alloys Comp. 334, 249-252 (2002)]. Therefore, this system is an ideal choice to gain a better understanding of the underlying mechanism of the MCE in multiple site driven magnetocaloric materials. A combination of macroscopic temperature dependent magnetization measurements on polycrystalline and single crystal samples and temperature dependent neutron and x-ray powder diffraction allows the establishment of a magnetic phase diagram of the system. Additionally lattice responses to the transitions were characterized.

MA 23.3 Tue 14:30 H32

Structure and magnetism of single crystal Mn_3GaC — •Franziska Scheibel, Detlef Spoddig, Ralf Meckenstock, Markus E. Gruner, Benjamin Zingsem, Michael Farle, and Mehmet Acet — Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg

Mn_3GaC undergoes a first-order magnetic transition from an antiferromagnetic to a ferromagnetic phase at T_i and a second-order magnetic transition from the ferromagnetic to the paramagnetic phase at T_C. A large reversible adiabatic temperature-change of $\Delta T_{ad} = 4.7$ K related to an entropy change of $\Delta S = 14$ $\mathrm{Jkg^{-1}K^{-1}}$ in 2 T field makes this compound interesting for magnetic refrigeration [1]. The magnetic properties of a 15x15x28 μm single crystal Mn_3GaC were studied using magnetometry and ferromagnetic resonance (FMR). The transition temperatures $T_i = 163$ K $T_C = 236$ K and the saturation magnetization of 0.41 $\mathrm{MAm^{-1}}$ at 200 K agree well with those of polycrystalline material. Temperature and orientation dependent FMR spectra show a dominant shape anisotropy compared to the magnetocrystalline anisotropy (-5 ± 1 $\mathrm{kJm^{-3}}$). The {111} direction is identified as the magnetic easy axis. The results are compared to micro magnetic simulations, free energy density and DFT calculations and are found to be in good agreement.

Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

[1] F. Scheibel et al., J. Appl. Phys. 117 (2015) 233902.

MA 23.4 Tue 14:45 H32

Inelastic neutron scattering on magnetocaloric compounds — •Nikolaos Biniskos[1], Karin Schmalzl[1], Stephane Raymond[2], and Thomas Brueckel[3] — [1]Juelich Center for Neutron Science JCNS, Forschungszentrum Juelich GmbH, Outstation at ILL, Grenoble, France — [2]CEA-Grenoble, INAC SPSMS MDN, Grenoble, France — [3]Juelich Centre for Neutron Science JCNS and Peter Gruenberg Institut PGI, JARA-FIT, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany

One way for saving energy in daily life is using the magnetocaloric effect (MCE), i.e. the change of magnetic entropy and adiabatic temperature following a change in an applied magnetic field. The ferromagnetic compound MnFe4Si3 (S.G.: P-6) is a promising candidate for applications. It has a magnetic phase transition in the range of 300 K and shows a moderate MCE of 2.9 J/kg K at a reasonable magnetic field change from 0 T to 2 T. In order to understand the fundamental driving force of the MCE in this material a study of magnetism, lattice dynamics and their interaction is necessary. Energy scans and q-scans first with non-polarized neutron scattering were carried out at energies mainly below 13meV looking for lattice (acoustic phonons) and magnetic excitations. Later these excitations were identified with polarized neutrons. Preliminary results at 1.5K indicate stronger magnetic interactions in [001] than [100] direction of the hexagonal system. Measurements with polarized neutrons above TC reveal sizable magnetic fluctuations in a significant large temperature range (300<T<500K). Magnetic fluctuations in the paramagnetic phase are found to be isotropic.

MA 23.5 Tue 15:00 H32

Designing cubic Heusler for magnetocaloric-based applications — •Luana Caron[1], Sanjay Singh[1], Sunil W. D'Souza[1], Tina Fichtner[1], Giacomo Porcari[2], Simone Fabbrici[3], Chandra Shekhar[1], Stanislav Chadov[1], Massimo Solzi[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Germany — [2]Parma University, Italy — [3]IMEM-CNR, Italy

Since the observation of a giant magnetocaloric effect (MCE) in $Gd_5Ge_2Si_2$, the search for materials for MCE-based applications has been focused on compounds showing 1^{st} order phase transitions. However, the practical application of giant MCE materials is hindered by the nature of the transition itself. In order to drive a 1^{st} order phase transition, energy is spent to overcome the energy barrier between different states. This energy loss leads to irreversibilities in both temperature and entropy changes in addition to discontinuous structural changes which cause physical instability. In this work we explore theoretically and experimentally how to obtain high magnetic moments in cubic $Ni_2(Mn,X)_2$ X= Ga, In, Sn Heusler alloys. Our aim is to design Heusler compounds presenting a combination of high ground state moment and a fully reversible 2^{nd} order phase transition for magnetocaloric cooling applications. Using ab initio calculations we have determined the exchange interactions and magnetic moments of these alloys in the cubic structure as to maximize the net saturation magnetization. As a proof of concept we present the magnetic and MCE properties of the $Ni_2Mn_{1.4}In_{0.6}$ compound which presents a calculated and measured saturation moment comparable to that of Gd.

MA 23.6 Tue 15:15 H32

Direct measurements of the adiabatic temperature change in shape memory alloys — •Lars Helmich[1], Niclas Teichert[1], Bruno Weise[2], Anja Waske[2], and Andreas Hütten[1] — [1]CSMD, Department of Physics, Bielefeld University, Bielefeld, Germany — [2]Institute for Complex Materials, IFW Dresden, Dresden, Germany

Magnetocaloric materials are highly promising candidates for efficient cooling devices. Thin film samples represent an ideal system in order to study their suitability for applications. Due to the small sample volume the measurement of the adiabatic temperature change is a challenging task.

Therefore we have set up a new custom-built device which detects Delta T by infrared thermography: The samples are mounted on a nitrogen cooled stage in vacuum giving access to a temperature range between 120K and 470K.

A versatile model for calibration of the infrared emissivity has been developed.

Literature values for bulk Gadolinium are well reproduced with our device. Furthermore the adiabatic temperature change was successfully measured on small-volume Gadolinium melt-spun ribbons. Besides, we have measured ΔT on various Ni-Mn-based Heusler alloys.

In particular we have investigated the Martensitic transformation and magnetic properties in off-stoichiometric NiCoMnAl melt-spun ribbons.

MA 24: Electronic Structure: Surface Magnetism and Spin Phenomena

Time: Tuesday 18:15–20:30 Location: Poster E

MA 24.1 Tue 18:15 Poster E

High-Mobility Sm-Doped Bi2Se3 Ferromagnetic Topological Insulators and Robust Exchange Coupling — •Taishi Chen — Max Plank Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Magnetically doped topological insulators (MTIs) are emerging as a new platform of dilute magnetic semiconductors (DMSs) as a result of growing interest in topological magnetoelectric effect, the quantum spin/anomalous Hall Effect, and Dirac fermion-mediated magnetic coupling physics [1]. However, the traditional transition metal magnetic elements doped topological insulators are often hindered by the inadequate material quality, which is demonstrated by the low mobility of the samples [2-4]. In this work [5], we show the successful preparation of a series of new Sm-doped Bi2Se3 MTIs, which exhibit ferromagnetism up to about 52 K and a suppressed bulk electron carrier concentration as low as 1018 cm*3 in order. Clear Shubnikov*de Haas oscillations are observed in these samples. All evidence suggests that Sm-doped Bi2Se3 is a candidate high-mobility MTI.

MA 24.2 Tue 18:15 Poster E

High-Mobility Sm-Doped Bi2Se3 Ferromagnetic Topological Insulators and Robust Exchange Coupling — •Taishi Chen — Max Plank Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Magnetically doped topological insulators (MTIs) are emerging as a new platform of dilute magnetic semiconductors (DMSs) as a result of growing interest in topological magnetoelectric effect, the quantum spin/anomalous Hall Effect, and Dirac fermion-mediated magnetic coupling physics [1]. However, the traditional transition metal magnetic elements doped topological insulators are often hindered by the inadequate material quality, which is demonstrated by the low mobility of the samples [2-4]. In this work [5], we show the successful preparation of a series of new Sm-doped Bi2Se3 MTIs, which exhibit ferromagnetism up to about 52 K and a suppressed bulk electron carrier concentration as low as 1018 cm*3 in order. Clear Shubnikov*de Haas oscillations are observed in these samples. All evidence suggests that Sm-doped Bi2Se3 is a candidate high-mobility MTI.

References [1] X. L. Qi, et al., Physical Review B 78, 195424 (2008). [2] C. Z. Chang, et al., Science 340, 6129, (2013). [3] C. Z. Chang, et al., Nature Materials 14, 5, (2015). [4] Y. L. Chen, et al., Science 329, 5992, (2010). [5] T. S. Chen, et al., Advanced Materials 27, 33, (2015).

MA 24.3 Tue 18:15 Poster E

Laser induced DC photocurrents in a Topological Insulator thin film — •Nina Meyer[1], Thomas Schumann[1], Dagmar Butkovicová[2], 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]Peter Grünberg Institute (PGI-9), Jülich, Germany

Recent experiments give evidence that the optical excitation of spin-polarized surface states of topological insulators (TI) can launch electron currents along the surface whose direction can be controlled by varying the polarization of the driving light [1]. We generated a photocurrent by illuminating TI (Bi, Sb)$_2$Te$_3$ thin films with laser light whose polarization changes periodically. The laser light was focused to a 6 μm spot on the device by an objective. We found and will discuss that the photocurrent has at least two parts on different time dynamics. Furthermore we determined different Parameters like [1] and show their dependence on polarization and additional experimental parameters. The films with a thickness of 20 nm were structured to Hall bar devices.

We acknowledge funding through DFG priority program SPP "Topological Insulators" and DAAD PPP Czech Republic "FemtomagTopo".
[1] J. W. McIver, D. Hsieh, H. Steinberg, P. Jarillo-Herrero and N. Gedik, Nature Nanotechnology 7, 96-100 (2012)

MA 24.4 Tue 18:15 Poster E

W(110) and Ta(110): A Playground for Spin-Orbit-Induced Effects on Surface States — •H. Wortelen[1], K. Miyamoto[2], H. Mirhosseini[3], B. Engelkamp[1], A.B. Schmidt[1], J. Henk[4], and M. Donath[1] — [1]Universität Münster — [2]HSRC, Hiroshima University — [3]MPI für Mikrostrukturphysik Halle — [4]Universität Halle-Wittenberg

The influence of spin-orbit effects on the surface electronic structure of W(110) and Ta(110) was investigated with spin- and angle-resolved photoemission and inverse photoemission experiments and electronic-structure calculations. We present a comprehensive $E(\mathbf{k}_\parallel)$ picture of the electronic states and their spin texture in the occupied and unoccupied regime.

Tungsten and tantalum, direct neighbors in the periodic table, exhibit a very similar electronic structure, yet with a shifted Fermi energy due to the one electron difference. Both elements exhibit a bcc crystal structure, however, with different lattice parameters resulting in differently pronounced hybridization of surface and bulk bands. As a consequence, a Dirac-cone-like surface state, reminiscent of a topological surface state, observed for W(110) below E_F [1,2] has no apparent equivalent on Ta(110), although it is expected above E_F [3]. Furthermore, a Rashba-split d_{z^2} surface state appears on Ta(110) [4], which has no equivalent on W(110).

[1] Miyamoto et al., Phys. Rev. Lett. **108**, 066808 (2012)
[2] Mirhosseini et al., New J. Phys. **15**, 033019 (2013)
[3] Engelkamp et al., Phys. Rev. B **92**, 085401 (2015)
[4] Wortelen et al., Phys. Rev. B **92**, 161408(R) (2015)

MA 24.5 Tue 18:15 Poster E

First-principles dynamical spin and charge currents in magnetic nanostructures — •Sascha Brinker, Filipe Souza Mendes Guimarães, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We investigate the spatial distribution of ground state and dynamical spin and charge currents in magnetic nanostructures from first-principles. We outline our density functional theory implementation in the Korringa-Kohn-Rostoker Green function method, in a real-space approach. Small magnetic nanostructures are considered, e.g. Fe adatoms, dimers and trimers on the Au(111) and Pt(111) surfaces. Our findings should be relevant for recent and future microscopy techniques [1].

Work funded by the HGF-YIG Programme FunSiLab – Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717).

[1] A. Lubk, A. Béché, and J. Verbeeck, Phys. Rev. Lett. **115**, 176101 (2015)

MA 24.6 Tue 18:15 Poster E

Bi/Ag(111) vs. Pb/Ag(111) along $\overline{\Gamma}\,\overline{\mathrm{M}}$ and $\overline{\Gamma}\,\overline{\mathrm{K}}$ – A comparative study of the unoccupied states — •Katharina T. Ritter[1], Sune N. P. Wissing[1], Anke B. Schmidt[1], Hossein Mirhosseini[2], Steven Achilles[3], Jürgen Henk[3], and Markus Donath[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

Surface alloys of heavy metal elements on noble metal surfaces exhibit strongly Rashba-split band structures. Especially surface alloys with $(\sqrt{3}\times\sqrt{3})R30^\circ$ reconstruction have been investigated over the last few years.

Here, we compare Bi/Ag(111) and Pb/Ag(111) systematically. We present spin- and angle-resolved inverse photoemission data for both high-symmetry directions $\overline{\Gamma}\,\overline{\mathrm{M}}$ and $\overline{\Gamma}\,\overline{\mathrm{K}}$. The experimental data is complemented by theoretical calculations.

Changing the adsorbate from Bi to Pb results in an energetic shift of the surface states and leads to a different size of the spin splitting. These changes are attributed to the adsorbate's atomic number, which is connected to the atomic spin-orbit coupling, as well as to its size, thus the relaxation of the surface.

MA 24.7 Tue 18:15 Poster E

Spin filtering in Bi superstructures on a Au(111) surface — Sebastian Jakobs[1,2], •Dominik Jungkenn[1], Christian Tusche[3], Jürgen Kirschner[3], Benjamin Stadtmüller[1], Mirko Cinchetti[1], Stefan Mathias[4], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Str 46, 67663 Kaiserslautern, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Erwin Schroedinger Straße 46, 67663 Kaiserslautern, Germany — [3]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 062120 Halle/Saale, Germany — [4]I. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Spin dependent scattering of electrons at interfaces is one of the most relevant microscopic processes that determine the performance of spintronics devices. However, the scattering process itself is hard to address experimentally. Here, we use spin-resolved momentum microscopy to investigate the scattering of photoelectrons from a Au(111) surface on Bi superstructures. We will show that the Bi/Au(111) interface constitutes a simple model system to understand spin dependent electron scattering processes on the microscopic level, since the spin polarization changes with the number and direction of scattering events.

MA 24.8 Tue 18:15 Poster E

Inelastic spin excitations and many-body effects in Fe porphins — •Laëtitia Farinacci, Nino Hatter, Sonja Schubert, Benjamin W. Heinrich, and Katharina J. Franke — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Magnetism of 3d metals in molecules is commonly treated by crystal field theory. Nonetheless, in case of strong hybridization of the d levels with ligand orbitals this approach may be insufficient. Modification of the conjugated π system could give insight in the influence of such hybridization effects.

Using STM and STS we investigate the properties of the H2P porphins adsorbed on Au(111). After deposition, only monomers are observed on the surface. Annealing to 630 K triggers their polymerization and metalation of the molecules is achieved by Fe deposition at 300 K.

In spectroscopy, FeP monomers and dimers present various features around the Fermi energy above their Fe centers as well as above specific parts of their molecular ligand. Depending on the nature and adsorption site of the molecules, steps localized at energies up to $\pm$ 14 mV as well as a zero bias anomaly similar to a Fano-line shape can be observed. These features result from an interplay between inelastic spin excitations and many-body effects: their shape, broadening and localization cannot be fully addressed by crystal field theory and have to be related to the mixing of the Fe d levels with organic orbitals reported by theory [1] as well as to various couplings to the substrate.

[1] M.E. Ali, et al., J. Phys. Chem. B 116, 5849 (2012).

MA 24.9 Tue 18:15 Poster E

Correlation effects in the surface electronic structure of Fe(110) — •Beatrice Andres, Marko Wietstruk, and Martin Weinelt — Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Beyond one-electron mean-field theories, electronic band energies are renormalized by many-body effects. Such a renormalization can directly be observed in photoemission as a kink in the band dispersion, where the band reaches the excitation energy of a quasi particle. In laser photoemission ($h\nu = 6.2$ eV) on Fe/W(110) we find an occupied surface band crossing the Fermi level at ~ 0.1 Å^{-1} in Γ-H direction. We observe a pronounced energy renormalization in this iron minority-spin surface state at 160 meV binding energy. Following Ref. [1], we assign this to a renormalization by magnon dressing of the surface electrons.

Applying spin-resolved photoemission, we are able to track the spin polarization of the surface band and ensure that the observed kink is not a trivial crossing of two bands. Our spin detection is based on exchange scattering at a magnetized Fe/W(001) target. By switching the magnetization of sample and scattering target separately, we are able to distinguish between spin polarization and dichroic effects in the photoemission process. Thereby, we find the magnetic-linear-dichroic contrast changing sign crossing the kink as expected for spin-momentum coupling.

[1] Jörg Schäfer, *Phys. Rev. Lett.* **92**, 097205 (2004)

MA 24.10 Tue 18:15 Poster E

Non-collinear spin-states in dilute 1D chains induced by Dzyaloshinskii-Moriya interaction — •Manuel Steinbrecher[1], Alexander Ako Khajetoorians[1,2], Jens Wiebe[1], and Roland Wiesendanger[1] — [1]INF, Hamburg University, 20355 Hamburg, Germany — [2]IMM, Radboud University, 6525 AJ Nijmegen, The Netherlands

Nanostructures of coupled atomic spins are of high interest for future spintronic applications. Therefore, a deep understanding of the behavior of single magnetic atoms deposited on metallic surfaces and of the coupling between several of these spins is mandatory. By using the tip of a scanning tunneling microscope as a tool, single atoms can be moved on a surface [1] to build artificial nanostructures. Realizing bottom-up fabricated 1D spin chains so far led to simple ferromagnetic [2] or antiferromagnetic [3] ground states described by Néel states [4,5]. When using a heavy spin-orbit coupling material, like a Pt(111) surface [6], as a substrate we showed that we can tune the strength of an anisotropic, indirect exchange interaction between indidivual Fe atoms, namely the Dzyaloshinskii-Moriya interaction [7]. With this knowledge we were able to build 1D spin chains and induce non-collinear spin states in the chains, resulting in exotic magnetic behavior. [1] Eigler and Schweizer, Nature **344**, 524 (1990); [2] Gambardella *et al.*, Nature **416**, 301 (2002); [3] Hirjibehedin *et al.*, Science **312**, 1021 (2006); [4] Khajetoorians *et al.*, Science **332**, 1062 (2011); [5] Khajetoorians *et al.*, Nat. Phys. **8**, 497 (2012); [6] Khajetoorians *et al.*, PRL **111**, 157204 (2013); [7] Khajetoorians *et al.*, Nat. Commun., submitted (2015)

MA 25: Transport: Graphene (Joint session of DS, DY, HL, MA, O and TT organized by TT)

Time: Wednesday 9:30–13:15 Location: H22

Invited Talk MA 25.1 Wed 9:30 H22

Ultrafast photo-thermoelectric currents in graphene — •Alexander Holleitner — Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, D-85748 Garching, Germany.

We show that photo-thermoelectric currents occur on a picosecond time-scale in graphene [1]. To this end, we apply an on-chip pump/probe photocurrent spectroscopy [2,3] to double-gated junctions of graphene. Our experiments reveal the interplay of photogenerated hot electrons with so-called photovoltaic currents. Moreover, we demonstrate that hot electrons allow to read-out an ultrafast non-radiative energy transfer from fluorescent emitters, namely nitrogen-vacancy centers in nano-diamonds. The non-radiative energy transfer can be exploited as an ultrafast, electronic read-out process of the electron spin in nitrogen vacancy centers in the diamond nanocrystals. The detection gives access to fast energy transfer processes, which have not yet been observed by fluorescence measurements because of quenching of the optical signal for short transfer distances [4].

We thank A. Brenneis, F. Schade, L. Gaudreau, M. Seifert, H. Karl, M.S. Brandt, H. Huebl, J.A. Garrido, F.H.L. Koppens, for a very fruitful collaboration, and the ERC-grant 'NanoREAL' for financial support.

[1] A. Brenneis et al., (2016)
[2] L. Prechtel et al., Nature Comm. **3**, 646 (2012)
[3] C. Kastl et al. Nature Comm. **6**, 6617 (2015)
[4] A. Brenneis et al. Nature Nanotech. **10**, 135 (2015)

MA 25.2 Wed 10:00 H22

Double-logarithmic velocity renormalization at the Dirac points of graphene — •Peter Kopietz, Anand Sharma, and Carsten Bauer — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Str. 1, 60438 Frankfurt

Using a functional renormalization group approach with partial bosonization in the forward scattering channel we reconsider the effect of long-range Coulomb interactions on the quasi-particle velocity v_k close to the Dirac points of graphene. In contrast to calculations based on perturbation theory and field theoretical renormalization group methods, we find that v_k is proportional to $\ln[\kappa_k/k]$ where k is the deviation of the quasiparticle momentum from the Dirac points and the cutoff scale κ_k vanishes logarithmically for small k. We show that this double-logarithmic singularity is compatible with experiments and with the known three-loop expansion of v_k which contains terms of order $\ln k$ and $\ln^2 k$.

MA 25.3 Wed 10:15 H22

Dirac fermion wave packets in oscillating potential barriers — Walter Pötz[1], Sergey E. Savel'ev[2], Peter Hänggi[3], and •Wolfgang Häusler[3] — [1]Karl Franzens Univ. Graz, Inst. Phys., A-8010 Graz, Austria — [2]Department of Physics, Loughborough University, Loughborough LE11 3TU, United Kingdom — [3]Institut für Physik, Univ. Augsburg, 86135 Augsburg, Germany

We integrate the time-dependent (2+1)D Dirac equation for massless fermions in graphene or topological insulator surfaces. A recently developed staggered-grid leap-frog scheme is employed [1,2]. We consider an initial Gaussian wave packet which moves in the x-direction towards a potential barrier that is homogeneous along y and oscillates periodically in time. As for the x-dependence, we investigate square-well, sinusoidal, and linear-ramp potential profiles. Small transversal momentum components k_y of the wave packet were analyzed analytically [3] and predicted to generate non-zero current densities j_y, even at normal incidence $k_y = 0$ [4]. These findings are consistent with the present numerical studies of particle-, current-, and spin-density. We also investigate massive fermions: regarding some properties they resemble massless fermions, regarding other properties, however, peculiar intrinsic oscillations, reminiscent of Zitterbewegung, appear.

[1] R. Hammer and W. Pötz, PRB **88**, 235119 (2013)
[2] R. Hammer *et al.*, J. Comp. Phys. **265**, 50 – 70 (2014)
[3] S.E. Savel'ev, W. Häusler, and P. Hänggi, PRL **109**, 226602 (2012)
[4] S.E. Savel'ev, W. Häusler, and P. Hänggi, EPJB **86**, 433 (2013).

MA 25.4 Wed 10:30 H22

Electric and magnetic control of electron guiding in graphene — •Ming-Hao Liu and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg

Electrons in graphene are known to behave like massless Dirac fermions, whose transport properties can be best revealed by experiments using ultra-clean graphene. Reliable quantum transport simulations for ballistic graphene is naturally a powerful tool for understanding and predicting high-quality transport experiments. In this talk we show gate-controlled electron guiding along electrically confined channels in suspended graphene, which is a combined work of our transport simulations and the experiment done by the Schönenberger group [1]. We have recently further applied our simulation (Green's function method within the scalable tight-binding model [2]) to revisit the transverse magnetic focusing experiment [3], where the guiding of the electrons is controlled by an external magnetic field, instead of electrical gates. Besides good agreement with the experiments [1,3], our simulations further allow for probing charge flow through an additional scanning probe tip.

[1] P. Rickhaus *et al.*, Nano Lett. **15**, 5819 (2015).
[2] M.-H. Liu *et al.*, Phys. Rev. Lett. **114**, 036601 (2015).
[3] T. Taychatanapat *et al.*, Nat. Phys. **9**, 225 (2013).

MA 25.5 Wed 10:45 H22

Current flow paths in deformed graphene: from quantum transport to classical trajectories in curved space — •Nikodem Szpak[1] and Thomas Stegmann[1,2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

We compare two contrasting approaches to the electronic transport in deformed graphene: a) the condensed matter approach in which current flow paths are obtained by applying the non-equilibrium Green's function (NEGF) method to the tight-binding model with local strain, b) the general relativistic approach in which classical trajectories of relativistic point particles moving in a curved surface with a pseudo-magnetic field are calculated. The connection between the two is established in the long-wave limit via an effective Dirac Hamiltonian in curved space. Geometrical optics approximation, applied to focused current beams, allows us to directly compare the wave and the particle pictures. We obtain very good numerical agreement between the quantum and the classical approaches for a fairly wide set of parameters. The presented method offers an enormous reduction of complexity from irregular tight-binding Hamiltonians defined on large lattices to geometric language for curved continuous surfaces. It facilitates a comfortable and efficient tool for predicting electronic transport properties in graphene nanostructures with complicated geometries, paving the way to new interesting transport phenomena such as bending or focusing (lensing) of currents depending on the shape of the deformation. It can be applied in designing ultrasensitive sensors or in nanoelectronics.

MA 25.6 Wed 11:00 H22

Trigonal Warping in Bilayer Graphene: Energy versus Entanglement Spectrum — •Sonja Predin, Paul Wenk, and John Schliemann — Institute for Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany

We present a mainly analytical study of the entanglement spectrum of Bernal-stacked graphene bilayers in the presence of trigonal warping in the energy spectrum. Upon tracing out one layer, the entanglement spectrum shows qualitative geometric differences to the energy spectrum of a graphene monolayer. However, topological quantities such as Berry phase type contributions to Chern numbers agree. The latter analysis involves not only the eigenvalues of the entanglement Hamiltonian but also its eigenvectors. We also discuss the entanglement spectra resulting from tracing out other sublattices.

15 min. break

MA 25.7 Wed 11:30 H22

Valley-based Cooper pair splitting via topologically confined channels in bilayer graphene — •Alexander Schroer[1], Peter G. Silvestrov[1], and Patrik Recher[1,2] — [1]Institut für Mathematische Physik, Technische Universität Braunschweig, D-38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology Braunschweig, D-38106 Braunschweig, Germany

Bilayer graphene hosts valley-chiral one-dimensional modes at domain walls between regions of different interlayer potential or stacking order. When such a channel is close to a superconductor, the two electrons of a Cooper pair, which tunnel into it, move in opposite directions because they belong to different valleys related by the time-reversal symmetry. This kinetic variant of Cooper pair splitting requires neither Coulomb repulsion nor energy filtering but is enforced by the robustness of the valley isospin in the absence of atomic-scale defects. We derive an effective normal/superconducting/normal (NSN) model of the channel in proximity to an s-wave superconductor, calculate the conductance of split and spin-entangled pairs, and interpret it as a result of *local* Andreev reflection, in contrast to the widespread identification of Cooper pair splitting with crossed Andreev reflection in an NSN geometry.

MA 25.8 Wed 11:45 H22

The decisive role of stacking faults for understanding transport in bilayer graphene — •Heiko B. Weber[1], Ferdinand Kisslinger[1], Christian Ott[1], and Sam Shallcross[2] — [1]Lehrstuhl für Angewandte Physik, FAU Erlangen-Nürnberg (FAU), Erlangen, Germany — [2]Lehrstuhl für Theoretische Festkörperphysik, FAU Erlangen-Nürnberg (FAU)

Charge transport in bilayer graphene provides rich low-temperature phenomena, often assigned to interaction-driven phase transitions. We will discuss charge transport in bilayer graphene in a single-particle picture, but including stacking faults. Such partial dislocations are unavoidable in bilayer graphene and were recently imaged [1]. Depending on details, partial dislocations can introduce improved conductance, fully insulating behaviour or linear magnetoresistance. The latter is reliably found in transport experiments at elevated temperatures [2].

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[2] F. Kisslinger, C. Ott, C. Heide, E. Kampert, B. Butz, E. Spiecker, S. Shallcross, H. B. Weber, Nature Phys. **11**, 650 (2015).

MA 25.9 Wed 12:00 H22

Linear magnetoresistance in two-dimensional disordered conductors — •Ferdinand Kisslinger[1], Christian Ott[1], Erik Kampert[2], and Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, FAU Erlangen-Nürnberg (FAU), Erlangen, Germany. — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany.

The recent observation of linear magnetoresistance (MR) in large-area bilayer graphene gives a key to the understanding of this old and barely understood phenomenon [1]. In bilayer graphene, it can be traced back to mosaic-like pattern of a partial dislocation network [2]. In this talk we discuss how linear MR evolves in disordered samples, using a two dimensional resistor network model conceptually introduced by Parish and Littlewood [3]. This model is in the weak disorder regime dominated by boundary effects. We identified a new regime representing the bulk situation in a disordered conductor. We investigated different possible sources of disorder: mobility, charge carrier density and network structure. The slope of the MR turned out to be simply governed by the Hall resistance and therefore by the inverse of the charge carrier density. An equivalent circuit model finally gives a consistent explanation as to why the magnetoresistance is linear in mosaic like samples.

[1] F. Kisslinger et al., Nature Physics **11**, 650 (2015)
[2] B. Butz et al., Nature **505**, 533 (2014).
[3] M. M. Parish & P. B. Littlewood, Nature **426**, 162 (2003)

MA 25.10 Wed 12:15 H22

Mechanically strained graphene nanojunctions — •Seddigheh Nikipar[1], Dmitry Ryndyk[1], and Gianaurelio Cuniberti[1,2] — [1]Institute for Materials Science and Max Bergmann Center of Bioma-

terials, TU Dresden, Germany — [2]Dresden Center for Computational Materials Science (DCMS), TU Dresden, Germany

It has been demonstrated recently that mechanically strained graphene presents interesting electrical properties, which have great potential for novel applications in electronic devices. In particular, the strain in graphene nanoribbons can lead to substantial changes in its electronic properties. Besides, it provides a possibility to develop atomic point contacts and break junctions. The main purpose of this work is to investigate theoretically the influence of uniaxial mechanical strains on graphene nanojunctions in order to design graphene point contact.

To this aim, we developed the computational model by combining density functional theory and molecular dynamics methods. First, we investigated the change of the junction shape with increasing strain and the breaking with the formation of the nanogap. As expected, our theoretical model predicts the deformation of the break junction bottleneck into carbon chains before the rupture of the structure. we evaluated the electronic transmission function of graphene quantum junction by employing a coupled tight bonding and nonequilibrium green function methods. Interestingly it is found that graphene point contact can present resonance transmission in contrast to the conventional metallic point contacts with quantized conductance. This might be originated from influence of other parameters on transmission.

MA 25.11 Wed 12:30 H22

Graphene nanoribbons as effective spin ladders — •Cornelie Koop, Manuel J. Schmidt, and Stefan Wessel — Institut für Theoretische Festkörperphysik, RWTH Aachen University

Zigzag edges of graphene nanoribbons host particular, localized edge states. Since the density of states is strongly enhanced near the edges in graphene, interaction effects between the spins of these edge states become important. We can significantly simplify the analysis of such systems by means of an effective model that separates the edge and bulk states. Treating the effective interactions to first order proves sufficient in most cases, while second order corrections do not dramatically change the results. In many cases, the edge system can be reduced to a general spin ladder model, where the decay of the spin-spin interaction is determined by the shape of the edges. We examine these effective spin ladders at finite temperatures by means of quantum Monte Carlo simulations, using the stochastic series expansion method. Thereby, correlation functions and spin structure factors can be determined for realistically large graphene nanoribbons.

MA 25.12 Wed 12:45 H22

Edge State Structure of the $\nu = 0$ quantum Hall State in monolayer Graphene — •Angelika Knothe[1,2] and Thierry Jolicoeur[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Université Paris 11, CNRS, LPTMS, UMR 8626, Orsay 91405 France

Single-layer graphene at neutrality under a magnetic field is a many-body insulator whose phase structure is under intense scrutiny. When tilting the applied magnetic field, there is a phase transition towards a conducting state [1]. A plausible description is to start from a SU(4) spin-valley symmetric quantum Hall ferromagnet and add some lattice-scale anisotropies in valley space [2]. In the manifold of ground states captured by this approach, it has been proposed that graphene undergoes a transition between a canted antiferromagnetic state and a ferromagnetic state. While this picture is clear in the bulk of the system, it remains to understand the effect of this phase change on the current-carrying edge states that are formed a the physical boundaries of a real sample [3]. We use an extended Hartree-Fock approach to describe a finite-size system with a simple model for the edge and extract the one-body spectrum. We then describe the current-carrying edge textures.

[1] A. F. Young et al., Nature (London) 505, 528 (2014) [2] M. Kharitonov, Phys. Rev. B 85, 155439 (2012) [3] M. Kharitonov, Phys. Rev. B 86, 075450 (2012); G. Murthy et al., Phys. Rev. B 90, 241410 (2014) and arXiv:1510.04255; A. Knothe and T. Jolicoeur, Phys. Rev. B 92, 165110 (2015)

MA 25.13 Wed 13:00 H22

Spin lifetimes exceeding 12 ns in graphene non-local spin valves at room temperature — •Christopher Franzen[1], Marc Drögeler[1], Frank Volmer[1], Tobias Pohlmann[1], Maik Wolter[1], Kenji Watanabe[2], Takashi Taniguchi[2], Christoph Stampfer[1], and Bernd Beschoten[1] — [1]2nd Institute of Physics and JARA-FIT, RWTH Aachen University, 52074 Aachen, Germany — [2]National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

We present spin transport measurements on graphene non-local spin transport devices by fabricating the electrodes first and subsequently transfer graphene with hexagonal boron nitride on top [1]. We achieve spin lifetimes of 12.6 ns and a spin diffusion length as high as 30 μm at room temperature.

This improvement exceeds all current models for contact-induced spin dephasing which paves the way towards probing intrinsic spin properties of graphene. Furthermore, we investigate the contact properties of our devices using scanning force microscopy (SFM) and conductive SFM. We discuss the importance of using large area hexagonal boron nitride for the transfer process and for achieving such high spin lifetimes and spin diffusion lengths.

[1] M. Drögeler *et al.* Nano Letters **14**, 6050 (2014).

MA 26: Transport: Graphene (Joint session of DS, DY, HL, MA, O and TT organized by TT)

Time: Wednesday 9:30–13:15 Location: H22

Invited Talk MA 26.1 Wed 9:30 H22

Ultrafast photo-thermoelectric currents in graphene — •Alexander Holleitner — Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, D-85748 Garching, Germany.

We show that photo-thermoelectric currents occur on a picosecond time-scale in graphene [1]. To this end, we apply an on-chip pump/probe photocurrent spectroscopy [2,3] to double-gated junctions of graphene. Our experiments reveal the interplay of photogenerated hot electrons with so-called photovoltaic currents. Moreover, we demonstrate that hot electrons allow to read-out an ultrafast non-radiative energy transfer from fluorescent emitters, namely nitrogen-vacancy centers in nano-diamonds. The non-radiative energy transfer can be exploited as an ultrafast, electronic read-out process of the electron spin in nitrogen vacancy centers in the diamond nanocrystals. The detection gives access to fast energy transfer processes, which have not yet been observed by fluorescence measurements because of quenching of the optical signal for short transfer distances [4].

We thank A. Brenneis, F. Schade, L. Gaudreau, M. Seifert, H. Karl, M.S. Brandt, H. Huebl, J.A. Garrido, F.H.L. Koppens, for a very fruitful collaboration, and the ERC-grant 'NanoREAL' for financial support.

[1] A. Brenneis et al., (2016)
[2] L. Prechtel et al., Nature Comm. **3**, 646 (2012)
[3] C. Kastl et al. Nature Comm. **6**, 6617 (2015)
[4] A. Brenneis et al. Nature Nanotech. **10**, 135 (2015)

MA 26.2 Wed 10:00 H22

Double-logarithmic velocity renormalization at the Dirac points of graphene — •Peter Kopietz, Anand Sharma, and Carsten Bauer — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Str. 1, 60438 Frankfurt

Using a functional renormalization group approach with partial bosonization in the forward scattering channel we reconsider the effect of long-range Coulomb interactions on the quasi-particle velocity v_k close to the Dirac points of graphene. In contrast to calculations based on perturbation theory and field theoretical renormalization group methods, we find that v_k is proportional to $\ln[\kappa_k/k]$ where k is the deviation of the quasiparticle momentum from the Dirac points and the cutoff scale κ_k vanishes logarithmically for small k. We show that this double-logarithmic singularity is compatible with experiments and with the known three-loop expansion of v_k which contains terms of order $\ln k$ and $\ln^2 k$.

MA 26.3 Wed 10:15 H22

Dirac fermion wave packets in oscillating potential barriers
— Walter Pötz[1], Sergey E. Savel'ev[2], Peter Hänggi[3], and •Wolfgang Häusler[3] — [1]Karl Franzens Univ. Graz, Inst. Phys., A-8010 Graz, Austria — [2]Department of Physics, Loughborough University, Loughborough LE11 3TU, United Kingdom — [3]Institut für Physik, Univ. Augsburg, 86135 Augsburg, Germany

We integrate the time-dependent (2+1)D Dirac equation for massless fermions in graphene or topological insulator surfaces. A recently developed staggered-grid leap-frog scheme is employed [1,2]. We consider an initial Gaussian wave packet which moves in the x-direction towards a potential barrier that is homogeneous along y and oscillates periodically in time. As for the x-dependence, we investigate square-well, sinusoidal, and linear-ramp potential profiles. Small transversal momentum components k_y of the wave packet were analyzed analytically [3] and predicted to generate non-zero current densities j_y, even at normal incidence $k_y = 0$ [4]. These findings are consistent with the present numerical studies of particle-, current-, and spin-density. We also investigate massive fermions: regarding some properties they resemble massless fermions, regarding other properties, however, peculiar intrinsic oscillations, reminiscent of Zitterbewegung, appear.

[1] R. Hammer and W. Pötz, PRB **88**, 235119 (2013)
[2] R. Hammer *et al.*, J. Comp. Phys. **265**, 50 – 70 (2014)
[3] S.E. Savel'ev, W. Häusler, and P. Hänggi, PRL **109**, 226602 (2012)
[4] S.E. Savel'ev, W. Häusler, and P. Hänggi, EPJB **86**, 433 (2013).

MA 26.4 Wed 10:30 H22

Electric and magnetic control of electron guiding in graphene
— •Ming-Hao Liu and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg

Electrons in graphene are known to behave like massless Dirac fermions, whose transport properties can be best revealed by experiments using ultra-clean graphene. Reliable quantum transport simulations for ballistic graphene is naturally a powerful tool for understanding and predicting high-quality transport experiments. In this talk we show gate-controlled electron guiding along electrically confined channels in suspended graphene, which is a combined work of our transport simulations and the experiment done by the Schönenberger group [1]. We have recently further applied our simulation (Green's function method within the scalable tight-binding model [2]) to revisit the transverse magnetic focusing experiment [3], where the guiding of the electrons is controlled by an external magnetic field, instead of electrical gates. Besides good agreement with the experiments [1,3], our simulations further allow for probing charge flow through an additional scanning probe tip.

[1] P. Rickhaus *et al.*, Nano Lett. **15**, 5819 (2015).
[2] M.-H. Liu *et al.*, Phys. Rev. Lett. **114**, 036601 (2015).
[3] T. Taychatanapat *et al.*, Nat. Phys. **9**, 225 (2013).

MA 26.5 Wed 10:45 H22

Current flow paths in deformed graphene: from quantum transport to classical trajectories in curved space
— •Nikodem Szpak[1] and Thomas Stegmann[1,2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

We compare two contrasting approaches to the electronic transport in deformed graphene: a) the condensed matter approach in which current flow paths are obtained by applying the non-equilibrium Green's function (NEGF) method to the tight-binding model with local strain, b) the general relativistic approach in which classical trajectories of relativistic point particles moving in a curved surface with a pseudo-magnetic field are calculated. The connection between the two is established in the long-wave limit via an effective Dirac Hamiltonian in curved space. Geometrical optics approximation, applied to focused current beams, allows us to directly compare the wave and the particle pictures. We obtain very good numerical agreement between the quantum and the classical approaches for a fairly wide set of parameters. The presented method offers an enormous reduction of complexity from irregular tight-binding Hamiltonians defined on large lattices to geometric language for curved continuous surfaces. It facilitates a comfortable and efficient tool for predicting electronic transport properties in graphene nanostructures with complicated geometries, paving the way to new interesting transport phenomena such as bending or focusing (lensing) of currents depending on the shape of the deformation. It can be applied in designing ultrasensitive sensors or in nanoelectronics.

MA 26.6 Wed 11:00 H22

Trigonal Warping in Bilayer Graphene: Energy versus Entanglement Spectrum
— •Sonja Predin, Paul Wenk, and John Schliemann — Institute for Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany

We present a mainly analytical study of the entanglement spectrum of Bernal-stacked graphene bilayers in the presence of trigonal warping in the energy spectrum. Upon tracing out one layer, the entanglement spectrum shows qualitative geometric differences to the energy spectrum of a graphene monolayer. However, topological quantities such as Berry phase type contributions to Chern numbers agree. The latter analysis involves not only the eigenvalues of the entanglement Hamiltonian but also its eigenvectors. We also discuss the entanglement spectra resulting from tracing out other sublattices.

15 min. break

MA 26.7 Wed 11:30 H22

Valley-based Cooper pair splitting via topologically confined channels in bilayer graphene
— •Alexander Schroer[1], Peter G. Silvestrov[1], and Patrik Recher[1,2] — [1]Institut für Mathematische Physik, Technische Universität Braunschweig, D-38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology Braunschweig, D-38106 Braunschweig, Germany

Bilayer graphene hosts valley-chiral one-dimensional modes at domain walls between regions of different interlayer potential or stacking order. When such a channel is close to a superconductor, the two electrons of a Cooper pair, which tunnel into it, move in opposite directions because they belong to different valleys related by the time-reversal symmetry. This kinetic variant of Cooper pair splitting requires neither Coulomb repulsion nor energy filtering but is enforced by the robustness of the valley isospin in the absence of atomic-scale defects. We derive an effective normal/superconducting/normal (NSN) model of the channel in proximity to an s-wave superconductor, calculate the conductance of split and spin-entangled pairs, and interpret it as a result of *local* Andreev reflection, in contrast to the widespread identification of Cooper pair splitting with crossed Andreev reflection in an NSN geometry.

MA 26.8 Wed 11:45 H22

The decisive role of stacking faults for understanding transport in bilayer graphene
— •Heiko B. Weber[1], Ferdinand Kisslinger[1], Christian Ott[1], and Sam Shallcross[2] — [1]Lehrstuhl für Angewandte Physik, FAU Erlangen-Nürnberg (FAU), Erlangen, Germany — [2]Lehrstuhl für Theoretische Festkörperphysik, FAU Erlangen-Nürnberg (FAU)

Charge transport in bilayer graphene provides rich low-temperature phenomena, often assigned to interaction-driven phase transitions. We will discuss charge transport in bilayer graphene in a single-particle picture, but including stacking faults. Such partial dislocations are unavoidable in bilayer graphene and were recently imaged [1]. Depending on details, partial dislocations can introduce improved conductance, fully insulating behaviour or linear magnetoresistance. The latter is reliably found in transport experiments at elevated temperatures [2].

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MA 26.9 Wed 12:00 H22

Linear magnetoresistance in two-dimensional disordered conductors
— •Ferdinand Kisslinger[1], Christian Ott[1], Erik Kampert[2], and Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik, FAU Erlangen-Nürnberg (FAU), Erlangen, Germany. — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany.

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MA 26.10 Wed 12:15 H22

Mechanically strained graphene nanojunctions — •Seddigheh Nikipar[1], Dmitry Ryndyk[1], and Gianaurelio Cuniberti[1,2] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, TU Dresden, Germany — [2]Dresden Center for Computational Materials Science (DCMS), TU Dresden, Germany

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To this aim, we developed the computational model by combining density functional theory and molecular dynamics methods. First, we investigated the change of the junction shape with increasing strain and the breaking with the formation of the nanogap. As expected, our theoretical model predicts the deformation of the break junction bottleneck into carbon chains before the rupture of the structure. we evaluated the electronic transmission function of graphene quantum junction by employing a coupled tight bonding and nonequilibrium green function methods. Interestingly it is found that graphene point contact can present resonance transmission in contrast to the conventional metallic point contacts with quantized conductance. This might be originated from influence of other parameters on transmission.

MA 26.11 Wed 12:30 H22

Graphene nanoribbons as effective spin ladders — •Cornelie Koop, Manuel J. Schmidt, and Stefan Wessel — Institut für Theoretische Festkörperphysik, RWTH Aachen University

Zigzag edges of graphene nanoribbons host particular, localized edge states. Since the density of states is strongly enhanced near the edges in graphene, interaction effects between the spins of these edge states become important. We can significantly simplify the analysis of such systems by means of an effective model that separates the edge and bulk states. Treating the effective interactions to first order proves sufficient in most cases, while second order corrections do not dramatically change the results. In many cases, the edge system can be reduced to a general spin ladder model, where the decay of the spin-spin interaction is determined by the shape of the edges. We examine these effective spin ladders at finite temperatures by means of quantum Monte Carlo simulations, using the stochastic series expansion method. Thereby, correlation functions and spin structure factors can be determined for realistically large graphene nanoribbons.

MA 26.12 Wed 12:45 H22

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MA 26.13 Wed 13:00 H22

Spin lifetimes exceeding 12 ns in graphene non-local spin valves at room temperature — •Christopher Franzen[1], Marc Drögeler[1], Frank Volmer[1], Tobias Pohlmann[1], Maik Wolter[1], Kenji Watanabe[2], Takashi Taniguchi[2], Christoph Stampfer[1], and Bernd Beschoten[1] — [1]2nd Institute of Physics and JARA-FIT, RWTH Aachen University, 52074 Aachen, Germany — [2]National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

We present spin transport measurements on graphene non-local spin transport devices by fabricating the electrodes first and subsequently transfer graphene with hexagonal boron nitride on top [1]. We achieve spin lifetimes of 12.6 ns and a spin diffusion length as high as 30 μm at room temperature.
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[1] M. Drögeler *et al.* Nano Letters **14**, 6050 (2014).

MA 27: Focus Session: Skyrmions meet Multiferroicity

Bridging the gap between multiferroicity and skyrmions, which are themselves of high importance for new electronic building blocks, is an upcoming challenge. Recently, magnetoelectric effects and ferroelectric phases were demonstrated in insulating skyrmion crystals comprising novel mechanisms of complex magnetic and unconventional ferroelectric order. The focus session introduces the new field of skyrmion dielectric solids and aims at an inspiring interdisciplinary discussion.

Organized by Stephan Krohns

Time: Wednesday 9:30–12:50 Location: H25

Topical Talk MA 27.1 Wed 9:30 H25

Functional domain walls in multiferroics — •Dennis Meier — ETH Zürich, Switzerland

During the last decade a wide variety of novel and fascinating correlation phenomena has been discovered at domain walls in multiferroic bulk systems, ranging from unusual electronic conductance to inseparably entangled spin and charge degrees of freedom. The domain walls represent quasi-2D functional objects that can be induced, positioned, and erased on demand, bearing considerable technological potential for future nanoelectronics. Most of the challenges that remain to be solved before turning related device paradigms into reality, however, still fall in the field of fundamental condensed matter physics and materials science. In my talk I will provide an overview of seminal experimental findings gained on electric and magnetic domain walls in multiferroic bulk materials. A special focus is put on the physical properties that emerge at so-called charged domain walls and the added functionality that arises from coexisting magnetic order. The goal is to draw attention to the persistent challenges and identify future key directions for

the research on functional domain walls in multiferroics.

MA 27.2 Wed 10:00 H25

Dielectric properties of the spin driven multiferroic linarite — •Alexander Ruff, Theresa Mack, Stephan Krohns, and Alois Loidl — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

In the last decade various mechanisms for coupled polar and magnetic ordering, so called multiferroicity, were discovered. Among various multiferroic systems, spin-driven ferroelectrics are in the scientific focus due to a close coupling of spin and charge leading to cross-link control of magnetic and electric order. These systems have noncollinear spin structures, e.g., magnetic phases with spiral or helical order. Thus, two canted neighbouring spins S_i and S_j allow for inverse Dzychaloshinskii-Moriya interaction resulting in spin-driven ferroelectric polarization P via P = Q x (S_i x S_j), where Q denotes the propagation vector of the spin spiral. Those complex magnetic phases often reveal unconventional magnetic behaviour, which can be found in frustrated quantum spin systems, like $LiCuVO_4$ or the naturally grown single crystal linarite, $PbCuSO_4(OH)_2$.

Here we present the dielectric properties as well as the ferroelectric polarization obtained via pyro- and magnetocurrent measurements, both in applied magnetic fields up to 9 T. Their analysis allows validating the theoretical prediction of P = Q x (S_i x S_j). Compared to prototypical $LiCuVO_4$, linarite crystallizes monoclinic leading to a more complex relation of crystallographic direction, ferroelectric polarization and spin spiral axis. Finally, we provide (H,T)-diagrams for the multiferroic phase of linarite.

Topical Talk MA 27.3 Wed 10:20 H25

Neutron scattering study of the cycloidal and Néel-type skyrmion lattice phases of GaV_4S_8 — •Sándor Bordács[1], Jonathan S White[2], Nicole Reynolds[2,3], Charles D Dewhurst[4], Henrik M Rønnow[3], Vladimir Tsurkan[5], Alois Loidl[5], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics, Budapest, Hungary — [2]Laboratory for Neutron Scattering and Imaging, PSI, Villigen, Switzerland — [3]Laboratory for Quantum Magnetism, EPFL, Lausanne, Switzerland — [4]Institut Laue-Langevin, Grenoble, France — [5]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

Recently, it was shown that not just whirlpool-like i.e. Bloch-type skyrmions but also Néel-type skyrmions formed by spin cycloids can exist in nature and the polar crystal symmetry of the Mott-insulator GaV_4S_8 can host this new kind of topological magnetic structures [1].

Here, we report the results of polarized small angle neutron scattering (SANS) experiments in the magnetically ordered phases of GaV_4S_8. We could experimentally demonstrate that the modulated magnetic states of GaV_4S_8 are formed by spin cycloids, thus, the helicity state of the skyrmions is compatible with the Néel type. Based on SANS experiments we also revealed that the orientation of the cycloidal wave vector is weakly pinned within the rhomboheral plane. Furthermore, the temperature vs. magnetic field phase diagram of GaV_4S_8 is systematically studied.

[1] I. Kézsmárki, et al., Nature Materials 14, 1116 (2015).

MA 27.4 Wed 10:50 H25

Real-space inspection of Skyrmion lattices with confined orientation in the multiferroic semiconductor GaV_4S_8 — •Erik Neuber[1], Peter Milde[1], Istvan Kézsmárki[2], and Lukas Eng[1] — [1]Institut für Angewandte Physik, TU Dresden, D-01069 Dresden, Germany — [2]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, Hungary

Following early predictions, skyrmion lattices (SkL) constituting a periodic array of spin vortices have now been reported to exist in various magnetic crystals mostly with chiral structure. Although non-chiral but polar crystals with C_{nv} symmetry were identified as ideal SkL hosts, this archetype of SkL has remained experimentally unexplored. In this contribution, we report on the discovery and real-space exploitation of a SkL in the multiferroic polar magnetic semiconductor GaV_4S_8 (GVS) that possesses rhombohedral (C_{3v}) symmetry and easy axis anisotropy [1]. The SkL exists over an unusally broad temperature range compared to other bulk SkL crystals, while the orientation of vortices is pinned along the magnetic easy axis and can not be controlled via external magnetic fields. Our investigation focuses on the real-space inspection of SkL in GVS using various scanning probe techniques.

[1] Kézsmarki et al., Nature Materials **14**, 1116-1122 (2015)

20 min. break

Topical Talk MA 27.5 Wed 11:30 H25

Collective spin excitations at GHz frequencies in Skyrmion-hosting bulk materials — •Dirk Grundler — Laboratoire des Matériaux Magnétiques Nanostructurés and Magnoniques, Institut des Matériaux, Faculté Science et Technique de l'Ingénieur, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

Skyrmion-hosting materials have generated great research efforts in fundamental and applied sciences. Collective spin excitations in the GHz frequency regime are in particular interesting as they provide information about the system's free energy and define response times in possible applications, respectively. We report on GHz spectroscopy performed on different bulk materials. For cubic chiral helimagnets supporting Bloch-type Skyrmions, such as insulating Cu_2OSeO_3 and semiconducting $Fe_{0.8}Co_{0.2}Si$, we found a universal behavior when studying the GHz response throughout the magnetic phase diagram (T. Schwarze *et al.*, Nat. Mater. **14**, 478 (2015)). Comparing with data from the polar magnetic semiconductor GaV_4S_8 supporting Néel-type Skyrmions (D. Ehlers *et al.*, arXiv:1512.02391), characteristic changes in the spectra are encountered that we attribute to an additional uniaxial magnetic anisotropy. We acknowledge financial support by the DFG via TRR80. The reported works are performed in cooperations with A. Bauer, H. Berger, D. Ehlers, T. Fehér, M. Garst, I. Kézsmárki, H.-A. Krug von Nidda, A. Leonov, A. Loidl, C. Pfleiderer, T. Schwarze, I. Stasinopoulos, V. Tsurkan, J. Waizner, and S. Weichselbaumer.

MA 27.6 Wed 12:00 H25

Skyrmions carrying electric polarization in multiferroic GaV_4S_8 — •Eugen Ruff[1], Sebastian Widmann[1], Peter Lunkenheimer[1], Vladimir Tsurkan[1,2], Sandor Bordács[3], Istvan Kézsmárki[1,3], and Alois Loidl[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg 86135, Germany. — [2]Institute of Applied Physics, Academy of Sciences of Moldova, Chisinau 2028, Republic of Moldova. — [3]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-Optical Spectroscopy Research Group, Budapest 1111, Hungary.

As predicted by Bogdanov *et al.*[1], recently a skyrmion lattice (SkL) was found in the magnetic semiconductor GaV_4S_8. Skyrmions, topologically protected spin textures, have a big potential for future applications in data storage. A crucial question is whether the SkL causes a ferroelectric polarization, which can be controlled by an electric field. In this contribution we study the magnetic and polar properties in the lacunar spinel GaV_4S_8. The system shows a structural transition at 44 K, associated with orbital order, and is known to have a complex magnetic phase diagram below 13 K. We show that already below 44 K the system reveals a sizable polarization[3] of 1 $\mu C/cm^2$. Furthermore also the magnetically ordered phases show spin driven excess polarizations, so GaV_4S_8 is multiferroic below 13 K.

[1]A. N. Bogdanov and A. Hubert, J. Magn. Magn. Mater. **138**, 255 (1994). [2]I. Kézsmárki *et al.*, Nat. Mater. **14**, 1116 (2015). [3]E. Ruff *et al.*, Sci. Adv. **1**, e1500916 (2015).

Topical Talk MA 27.7 Wed 12:20 H25

Skyrmionic states in ferroelectric nanocomposites — Yousra Nahas[1], •Sergei Prokhorenko[1,2], Lydie Louis[3], Zhigang Gui[4], Igor Kornev[5], and Laurent Bellaiche[1] — [1]University of Arkansas, Fayetteville, Arkansas, USA — [2]University of Liege, Liege, Belgium — [3]University of Connecticut, Storrs, Connecticut, USA — [4]University of Delaware, Newark, Delaware,USA — [5]Ecole Centrale Paris, Chatenay-Malabry, France

Non-coplanar swirling field textures, or skyrmions, are now widely recognized as objects of both fundamental interest and technological relevance. So far, skyrmions were amply investigated in magnets, where due to the presence of chiral interactions, these topological objects were found to be intrinsically stabilized. Ferroelectrics on the other hand, lacking such chiral interactions, were somewhat left aside in this quest. Here we demonstrate, via the use of a first-principles-based framework, that skyrmionic configuration of polarization can be extrinsically stabilized in ferroelectric nanocomposites. The interplay between the considered confined geometry and the dipolar interaction underlying the ferroelectric phase instability induces skyrmionic configurations. The topological structure of the obtained electrical skyrmion can be mapped onto the topology of domain-wall junctions. Furthermore, the stabilized electrical skyrmion can be as small as a few nanometers, thus revealing prospective skyrmion-based applications of ferroelectric nanocomposites.

MA 28: Surface Magnetism I (jointly with O)

Time: Wednesday 9:30–12:00 Location: H31

MA 28.1 Wed 9:30 H31

Design and Synthesis of a Blatter Radical for Stable Thin Films — •Francesca Ciccullo[1], Nolan Gallagher[2], Andrzej Rajca Rajca[2], and Maria Benedetta Casu[1] — [1]Institute of Physical and Theoretical Chemistry, University of Tübingen, Auf der Morgenstelle 18, 72076 Tübingen, Germany — [2]Department of Chemistry, University of Nebraska, Lincoln, Nebraska 68588-0304, United States

Organic radicals are fascinating materials because of their unique properties, which make them suitable for a variety of possible applications. Their synthesis may be challenging and big efforts have focused on chemical stability. However, introducing a new material in electronics requires not only chemically stable molecules but also stable thin films in view of their use in devices. In this work we have synthesized and characterized a derivative of the Blatter radical, bearing in mind the thermodynamic factors that govern thin film stability. We have proved our concept by investigating the electronic structure, the paramagnetic character and stability of the obtained films under UHV and ambient conditions, by in-situ X-ray photoelectron spectroscopy, ex-situ atomic force microscopy and electron paramagnetic resonance spectroscopy.

MA 28.2 Wed 9:45 H31

Co-Salen on NiO(001): Indication of a superexchange mediated coupling between a magnetic molecule and an antiferromagnetic bulk insulating substrate — •Alexander Schwarz, Josef Grenz, and Roland Wiesendanger — INF (IAP), Fachbereich Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Spin Polarized Scanning Tunneling Microscopy (SP-STM) and X-ray magnetic circular dichroism (XMCD) have been employed to detect the magnetic coupling between a magnetic surface and magnetic molecules adsorbed on top [1,2]. However, up to now only metallic substrates were investigated.

Here, we utilize Magnetic Exchange Force Microscopy (MExFM), which can be applied to insulating sample system [3]. This enables us to study the magnetic coupling between Co-Salen and the row-wise antiferromagnetically ordered spins on the (001) surface of a NiO single crystal, a wide band gap insulator. Using magnetically coated tips we find that Co-Salen molecules, which adsorb on neighboring oxygen rows, exhibit a significantly different apparent height. This observation can be explained by a magnetic contribution to the total tip-sample interaction. As on this substrate the molecule adsorbs with its central cobalt atom above oxygen, a superexchange mechanism could be responsible for the magnetic coupling between the spin-carrying nickel atoms of the subsurface layer and the cobalt atoms of the molecules.

[1] H. Wende at al., Nature Mat. **6**, 516 (2007).
[2] C. Iacovita et al., Phys. Rev. Lett. **101**, 116602 (2008).
[3] U. Kaiser, A. Schwarz, R. Wiesendanger, Nature **446**, 522 (2007).

MA 28.3 Wed 10:00 H31

Magnetic interlayer softening induced by molecular skyhook effect — •Rico Friedrich, Vasile Caciuc, Nicolae Atodiresei, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

The ability to tune surface magnetic exchange interactions by the adsorption of nonmagnetic organic molecules has opened a new direction of molecular spintronics research in which the magnetic properties of a substrate can be patterned down to the molecular scale [1,2,3]. Phenalenyl-based molecules deposited on a Co(111) substrate can magnetically decouple the Co atoms below the molecule from the bulk Co substrate leading to an experimentally measured interface magnetoresistance [2]. By systematically investigating weakly and strongly chemisorbed molecules as dioxan and dioxin on the prototypical ferromagnetic substrate of 2 monolayers Fe on W(110) we show that the inter-layer magnetic softening is the consequence of an increased distance between the first layer magnetic atoms directly binding the molecule and the second layer [4]. This molecular induced skyhook effect is present for both weakly and strongly chemisorbed molecules. Moreover, by increasing the molecule-surface hybridization the interlayer magnetic softening is enhanced due to a chemical contribution.

[1] M. Callsen *et al.*, PRL **111**, 106805 (2013)
[2] K. V. Raman *et al.*, Nature **493**, 509 (2013)
[3] R. Friedrich *et al.*, PRB **91**, 115432 (2015)
[4] R. Friedrich *et al.*, PRB **92**, 195407 (2015)

MA 28.4 Wed 10:15 H31

Non-collinear magnetic order at room temperature — •Aurore Finco, Pin-Jui Hsu, Thomas Eelbo, Niklas Romming, André Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

Non-collinear magnetic structures like skyrmions are very promising for spintronics applications. They can be stabilized in ultrathin films by the Dzyaloshinskii-Moriya interaction induced by the interface between a heavy element substrate and the magnetic layer. Spin-polarized scanning tunneling microscopy is a very powerful tool to investigate these complex spin structures down to the atomic scale. Using this technique, it was shown that the magnetic structure of the 1st layer Fe on Ir(111) is a nanoskyrmion lattice below 30 K [1]. Going to higher Fe coverage, an increased thermal stability can be expected.

At low temperature, spin spirals guided by reconstruction lines (due to lattice mismatch between Fe and Ir) are visible on both the 2nd [2] and the 3rd layer Fe on Ir(111) with periodicities of about 1.5-2 nm and 4-9 nm respectively. While the 2nd layer does not respond to a magnetic field, the 3rd layer spirals transform into single distorted skyrmions under an out-of-plane field of about 2 T. In the absence of a field, the measurement temperature was raised up to room temperature. On the 2nd layer, the cycloidal spin spirals disappear above 150 K whereas the 3rd and 4th layers exhibit a non-collinear magnetic structure at room temperature with a periodicity of 30 to 60 nm.

[1] Sonntag et al, PRL, 113 077202 ; [2] Hsu et al, PRL, in press

15 min. break

MA 28.5 Wed 10:45 H31

Evidence for non-collinear surface magnetic order of Gd(0001) by spin-polarized scanning tunneling microscopy — •Matthias Vogt, Martin Schmitt, Jeannette Kemmer, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We present spin-polarized scanning tunneling microscopy measurements of Gd(0001) films grown on W(110). In agreement with previous publications [1] we observed an exchange-split surface state with an occupied majority and an empty minority part. For film thicknesses between 6 and 240 atomic layers maps of the differential conductivity dI/dU measured with magnetically coated probe tips show a magnetic structure which is dominated by six contrast levels. They represent magnetic domains which are most likely the consequence of the hexagonal Gd surface structure, which results in six equivalent easy axis, similar to earlier reports on Dy(0001) films [2]. Additionally, close inspection reveals weak intensity modulations within the domains with a periodicity of about 2 nm. Their amplitude is strongly bias dependent and varies for different domains. The fact that these modulations are absent if measured with non-magnetic tips indicates their magnetic origin. We will present different potential non-collinear spin configurations and discuss to what extend they agree with our experimental observations.

[1] M. Bode *et al.*, Phys. Rev. Lett. **81**, 4256 (1998).
[2] L. Berbil-Bautista *et al.*, Phys. Rev. B **76**, 064411 (2007).

MA 28.6 Wed 11:00 H31

Modification of spin Hamiltonian induced by molecular deformation of 3d β-diketonate complexes — •Hironari Isshiki, Jinjie Chen, Clemens Baretzky, Timofey Balashov, and Wulf

Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology

The magnetic anisotropy of a magnetic molecule is governed to the ligand field around the magnetic ion. The magnetic properties might be altered greatly by the deformation of the molecule. Recently, the tuning of magnetic anisotropy by molecular deformation of Fe-porphyrin was demonstrated [1].

Here, we investigated the alternation of magnetic properties by tip induced ligand deformation on 3d metals based β-diketonate complexes with scanning tunneling microscopy. We observed an inelastic excitation at 10 meV on a Co(II) molecule in dI/dV spectra, which is attributed to a spin-flip excitation. Approaching the tip to the molecule, a discontinuous change in current was observed, indicating contact formation and molecular deformation. Accompanying the deformation, an appearance of a Kondo resonance and a shift of the energy of the inelastic excitation were observed. We carried out similar measurements on Ni(II) and Cu(II) molecules.

[1] Nano Lett., 2015, 15, 4024-4028

MA 28.7 Wed 11:15 H31

Local dynamics of topological magnetic defects imaged by magnetic force microscopy — •Peggy Schönherr[1], Anders Bergman[2], Markus Garst[3], Yoshi Tokura[4,5], Christian Degen[1], Manfred Fiebig[1], and Dennis Meier[1] — [1]ETH Zürich, Switzerland — [2]Uppsala University, Sweden — [3]Universität zu Köln, Germany — [4]University of Tokyo, Japan — [5]Riken, Japan

Chiral magnetic interactions induce complex spin textures, including helical and conical spin waves, as well as particle-like objects (skyrmions or merons), forming the basis for innovative device paradigms and exotic topological phenomena. Present key questions address the dynamics of the spin system and emergent topological defects. Here we discuss the micromagnetic dynamics in the helimagnetic phase of FeGe using magnetic force microscopic. We show that the nanoscale dynamics are governed by the depinning and subsequent motion of magnetic edge dislocations. The motion of these topologically stable objects triggers perturbations that can propagate over mesoscopic length scales. The experimental observation of stochastic instabilities in the micromagnetic structure provides new insight to the spatio-temporal dynamics of itinerant helimagnets and topological defects, and discloses novel challenges regarding their technological usage.

MA 28.8 Wed 11:30 H31

High frequency magnetization dynamics of individual atomic-scale magnets — •Stefan Krause, Andreas Sonntag, Jan Hermenau, Johannes Friedlein, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Nucleation, annihilation and domain wall propagation are the most fundamental microscopic processes of magnetization reversal. Understanding and controlling these mechanisms is crucial for the development of future high-speed spintronic applications. In previous spin-polarized scanning tunneling microscopy (SP-STM) studies it was shown that the thermally activated magnetization reversal of Fe/W(110) nanomagnets consisting of less than 100 atoms is realized by nucleation and propagation instead of a coherent rotation of all magnetic moments. [1]

Within the present study we use SP-STM to investigate the magnetic ground state dynamics of individual nanomagnets over a wide temperature ($T = 30..70$ K) and switching rate ($\nu = 100$ mHz..10 MHz) regime, combining telegraphic noise analysis and pump-probe schemes. With increasing T a transition between two Arrhenius regimes is observed, resulting in switching rates that are by orders of magnitude lower than expected from an extrapolation from the low temperature regime. The experimental results will be presented and interpreted in terms of an analytical model that accounts for the interplay of T-dependent nucleation, annihilation and propagation rates.

[1] S. Krause *et al.*, Phys. Rev. Lett. **103**, 127202 (2009).

MA 28.9 Wed 11:45 H31

Dynamical para-spin-excitations in non-magnetic adatoms — •Julen Ibañez-Azpiroz, Manuel dos Santos Dias, Stefan Blügel, and Samir Lounis — Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We find the presence of spin-excitation modes in non-magnetic adatoms, *i.e.* para-spin-excitation modes, the analogous of paramagnons in bulk materials. We show that their signature in the excitation spectrum can evolve a well-defined peak whose linewidth (*i.e.* inverse lifetime) is predominantly controled by the Stoner exchange parameter and the density of states near the Fermi level. Utilizing time-dependent density functional theory as implemented in the Korringa-Kohn-Rostoker Green function formalism, we explore the para-spin-excitations of various 4d transition-metal adatoms deposited on metallic substrates. Based on the Anderson impurity model, we identify the most favourable parameter setup for the appearance of such excitations. Finally, we simulate tunneling transport experiments to address the possibility of detecting these para-spin-excitations in inelastic scanning tunneling spectroscopy.

Funding provided by HGF-YIG Programme VH-NG-717 (Funsilab) and and the *Impuls und Vernetzungsfonds der Helmholtz-Gemeinschaft (Postdoc Programm).*

MA 29: Spintronics (incl. quantum dynamics) (jointly with HL, TT)

Time: Wednesday 9:30–12:15 Location: H32

MA 29.1 Wed 9:30 H32

Valley polarization in magnetically doped single-layer transition-metal dichalcogenides — •Udo Schwingenschlögl, Yingchun Cheng, and Qingyun Zhang — PSE Division, KAUST, Thuwal 23955, Saudi Arabia

We demonstrate that valley polarization can be induced and controlled in semiconducting single-layer transition-metal dichalcogenides by magnetic doping, which is important for spintronics, valleytronics, and photonics devices. As an example, we investigate Mn-doped MoS_2 by first-principles calculations. We study how the valley polarization depends on the strength of the spin orbit coupling and the exchange interaction and discuss how it can be controlled by magnetic doping. Valley polarization by magnetic doping is also expected for other honeycomb materials with strong spin orbit coupling and the absence of inversion symmetry. Reference: Phys. Rev. B **89**, 155429 (2014).

MA 29.2 Wed 9:45 H32

Giant Rashba-type spin splitting in ferroelectric GeTe(111) — •Marcus Liebmann[1], Christian Rinaldi[2], Domenico Di Sante[3], Jens Kellner[1], Christian Pauly[1], Rui Ning Wang[4], Jos Emiel Boschker[4], Alessandro Guissani[4], Stefano Bertoli[2], Matteo Cantoni[2], Lorenzo Baldrati[2], Marco Asa[2], Ivana Vobornik[5], Giancarlo Panaccione[5], Dmitry Marchenko[6], Jaime Sanchez-Barriga[7], Oliver Rader[7], Raffaella Calarco[4], Silvia Picozzi[3], Riccardo Bertacco[2], and Markus Morgenstern[1] — [1]II. Inst. Phys. B, RWTH Aachen University — [2]Politecnico di Milano, Italy — [3]Consiglio Nazionale delle Ricerche, L'Aquila, Italy — [4]Paul-Drude-Institut für Festkörperelektronik, Berlin — [5]Consiglio Nazionale delle Ricerche, Trieste, Italy — [6]Physikalische und Theoretische Chemie, Freie Universität Berlin — [7]Helmholtz-Zentrum für Materialien und Energie, BESSY, Berlin

The ferroelectric semiconductor GeTe has been proposed to exhibit a giant spin splitting of bulk Rashba bands with spin rotation direction coupled to the dielectric polarization [1]. We probe GeTe(111) grown by MBE using in-situ angular-resolved photoelectron spectroscopy (ARPES). We identify a novel Rashba-split surface band with giant spin splitting and find signatures of the bulk Rashba band by comparison with density functional theory calculations [2]. The ferroelectric polarization, as determined by piezo force microscopy, agrees with the predicted helical spin-momentum relation of the Rashba bands.

[1] D. Di Sante *et al.*, Adv. Mater. **25**, 509 (2013).
[2] M. Liebmann *et al.*, Adv. Mater. 2015, 10.1002/adma.201503459.

MA 29.3 Wed 10:00 H32

Spin Mapping of Surface and Bulk Rashba States in Ferro-

electric α-GeTe(111) Films — •H. J. Elmers[1], R. Wallauer[1], M. Liebmann[2], J. Kellner[2], M. Morgenstern[2], R.N. Wang[3], J.E. Boschker[3], R. Calarco[3], O. Rader[4], D. Kutnyakhov[1], S.V. Chernov[1], K. Medjanik[1], C. Tusche[5], M. Ellguth[5], H. Volfova[6], J. Braun[6], J. Minar[6], H. Ebert[6], and G. Schönhense[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]II. Physikalisches Institut B and JARA-FIT, RWTH Aachen — [3]Paul-Drude-Institut für Festkörperelektronik, Berlin — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin — [5]Max Planck Institute for Microstructure Physics, Halle — [6]Department Chemie, Ludwig-Maximilians-Universität München

Ferroelectric semiconductors like GeTe promise a switchable Rashba-parameter for electronic bulk states. A comprehensive mapping of the spin polarization of the electronic bands in α-GeTe(111) films has been performed using a time-of-flight momentum microscope equipped with an imaging spin filter that enables a simultaneous measurement of more than 10.000 data points. In addition to the Rashba type splitting of surface bands we observe a spin splitting of bulk bands with opposite spin helicity of the inner and outer Rashba bands revealing the complex spin texture at the Fermi energy that determines electronic transport.

MA 29.4 Wed 10:15 H32

Optically and thermally driven spin dynamics and quantum Otto cycles on Ni_4 structures — •Stefan Sold[1], Bhaskar Kamble[2], Georgios Lefkidis[1], and Wolfgang Hübner[1] — [1]Departement of physics, University of Kaiserslautern and Research Center OPTIMAS, Germany — [2]Asia Pacific Center for Theoretical Physics, Pohang, Korea

We present two different kinds of combined optical and thermodynamic processes on the chain-like prototypical Ni_4 cluster, described on the basis of high-level quantum chemistry. The one consists of incoherent spin relaxation and thermalization processes, the other one of a nano Otto engine.

First, we model various temperature profiles by coupling to one or two temperature baths. The system dynamics is mathematically described with the Lindblad superoperator [1]. We find that the inhomogeneous temperature profile, giving rise to non-equilibrium mixed states, induces non-uniform spin-density distribution (spin Seebeck effect on the nano scale).

Second, we propose a quantum Otto motor [2], which benefits from the spin degree of freedom and the energy discretization of the cluster, and may thus surpass the efficiency limit of classical Carnot cycles [3].

[1] G. Schaller and T. Brandes, Phys. Rev. A **78**, 022106 (2008)
[2] W. Hübner, G. Lefkidis, C. D. Dong, D. Chaudhuri, L. Chotorlishvili, and J. Berakdar, Phys. Rev. B **90**, 024401 (2014)
[3] C. D. Dong, G. Lefkidis, and W. Hübner, Phys. Rev. B **88**, 214421 (2013)

MA 29.5 Wed 10:30 H32

Theoretical aspects of the Edelstein effect for anisotropic 2DEGs and topological insulators — •Annika Johansson[1,2], Dmitry Fedorov[1,2], 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

A charge current driven through a two-dimensional electron gas (2DEG) with Rashba spin-orbit coupling [1] generates a spatially homogeneous spin polarization perpendicular to the applied electric field. This phenomenon is the Edelstein effect [2].

For selected model systems, we consider the Edelstein effect within the semiclassical Boltzmann transport theory. Its energy dependence is investigated, in particular the regime below the Dirac point of the 2DEG. In addition to an isotropic 2DEG [1], we analyze systems with anisotropic Fermi contours. We predict that the current-induced spin polarization vanishes if the Fermi contour passes through a Lifshitz transition. In addition, we corroborate that topological insulators provide a very efficient conversion of charge to spin current [3].

Our findings for paradigmatic Rashba systems call for experimental verification.

[1] Y. Bychokov and E. Rashba, J. Phys. C, **17**, 6039 (1984) [2] V. M. Edelstein, Solid State Commun., **73**, 233 (1990) [3] J. C. Rojas Sánchez *et al.*, ArXiv: 1509.02973 (2015)

15 min. break

MA 29.6 Wed 11:00 H32

Spin superfluidity and long-range transport in thin-film ferromagnets — Hans Skarsvåg, •Cecilia Holmqvist, and Arne Brataas — Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

In ferromagnets, magnons may condense into a single quantum state. Analogous to superconductors, this quantum state may support transport without dissipation. Recent works suggest that longitudinal spin transport through a thin-film ferromagnet is an example of spin superfluidity. Although intriguing, this tantalizing picture ignores long-range dipole interactions; here, we demonstrate that such interactions dramatically affect spin transport. In single-film ferromagnets, "spin superfluidity" only exists at length scales (a few hundred nanometers in yttrium iron garnet) somewhat larger than the exchange length. Over longer distances, dipolar interactions destroy spin superfluidity. Nevertheless, we predict the re-emergence of spin superfluidity in tri-layer ferromagnet-normal metal-ferromagnet films that are ~1 micrometre in size. Such systems also exhibit other types of long-range spin transport in samples that are several micrometers in size.

MA 29.7 Wed 11:15 H32

Ultra-long electron and hole spin lifetimes in monolayer WSe_2 — Sammy Pissinger, •Robin de Winter, Christopher Franzen, Manfred Ersfeld, Sebastian Kuhlen, Christoph Stampfer, and Bernd Beschoten — 2nd Institute of Physics and JARA-FIT, RWTH Aachen University, Germany

There is strong interest in optical generation and detection of valley spin polarizations in transition metal dichalcogenides. We report on time-resolved two color pump probe Kerr rotation measurements on mechanically exfoliated monolayer WSe_2 crystals. We find electron and hole spin lifetimes of up to 100 ns at low temperatures. These values are in good agreement with exciton lifetimes extracted from all-optical time-resolved reflectivity indicating that the spin lifetimes are limited by exciton recombination times in our crystals. Electron spin precession in Voigt geometry furthermore reveals inhomogeneous spin dephasing caused by a large spread in the local g factors.

MA 29.8 Wed 11:30 H32

Bulk Spin-Orbit Torques at finite temperatures in Bulk Half-Metallic Heuslers from First Principle — •Jacob Gayles[1], Libor Šmejkal[2], Jakub Železny[2], Frank Freimuth[3], Zhe Yuan[1], Yuriy Mokrousov[3], Tomas Jungwirth[2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]Institute of Physics ASCR, v.v.i., Cukrovarnicka 10, 162 53 Praha 6 Czech Republic — [3]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We predict bulk spin-orbit torques in the half-metallic Heuslers NiMnSb and PtMnSb, using symmetry arguments in conjunction with first principle calculations. We present under uniaxial growth strain a linear dependence of the even torque and that can be tuned to zero while observing a sizable odd torque is independent of strain. Furthermore, these effects are seen to be two orders of magnitude larger in the PtMnSb. The even torque is strongly dependent on the temperature decreasing by 75% at room temperature where finite temperature is taken into account in the frozen phonon approximation. We show the equivalence of two widely used methods, the Landauer-Bütikker and the Kubo linear response formalism giving confidence in our result for experimental measurements in bulk magnetic Heusler compounds breaking inversion symmetry.

MA 29.9 Wed 11:45 H32

Dynamics of bound monopoles in artificial spin ice: How to store energy in Dirac strings. — •Elena Vedmedenko — University of Hamburg, Hamburg, Germany

Dirac strings in spin-ices are lines of reversed dipoles joining two quasi-particle excitations. These excitations behave themselves as unbound emergent monopoles if the tension of Dirac strings vanishes. In this work analytical and numerical analysis are used to study dynamics of two-dimensional dipolar spin ices, artificially created analogs of bulk spin-ice, in the regime of bound monopoles. It is shown that in this regime strings rather than monopoles are effective degrees of freedom explaining the finite-width band of Pauling states. A measurable prediction of path-time dependence of endpoints of stretched and then released Dirac string is made and verified via simulations. It is shown that string dynamics is defined by the characteristic tension-to-mass ratio, which is determined by the fine structure constant and lattice dependent parameter. It is proposed to use string tension to achieve spontaneous magnetic currents. A concept of energy storing device on the basis of this principle is proposed and illustrated by an experimental demonstration. A scheme of independent measurement at the nanoscale is proposed.

MA 29.10 Wed 12:00 H32

Spin-orbit torque in antiferromagnets — •Jakub Zelezny[1], Frank Freimuth[2], Yuriy Mokrousov[2], Jacob Gayles[3], Jairo Sinova[3], and Tomas Jungwirth[3] — [1]Institute of Physics of the Czech Academy of Sciences, Czech Republic — [2]Forschungszentrum Julich and JARA, Germany — [3]Institut fur Physik, Johannes Gutenberg Universitat Mainz, Germany

Antiferromagnets are common in nature and just like ferromagnets posses a long-range magnetic order. Unlike ferromagnets though, they have found little practical applications so far, primarily due to their lack of total magnetization. However, development of spintronics opens up ways how they could be used. Antiferromagnets have some advantages over ferromagnets, in particular ultrafast magnetization dynamics and wide range of materials available, including many semiconductors. One of the key problems for application of antiferromagnets in spintronics remains manipulation of the spin-axis. Recently we have predicted that in some bulk antiferromagnets, electrical current can effectively manipulate the magnetic moments [1]. Switching of an antiferromagnet using this method have recently been observed experimentally [2]. The effect is analogous to the spin-orbit torque in ferromagnets. Here we discuss the symmetry of the torques, especially the necessary conditions for their existence and show results of microscopic calculation of the torques in various antiferromagnets.

[1] J. Železný et al., PRL 113 (15), 157201 [2] P. Wadley et al., Science, to be published, arXiv:1503.03765

MA 30: Spin-Torque Phenomena

Time: Wednesday 9:30–13:15 Location: H33

Invited Talk MA 30.1 Wed 9:30 H33

Spin-orbit torques and charge pumping in crystalline magnets — •Chiara Ciccarelli — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE

In magnetic crystals with an inversion asymmetric unit cell a non-zero global spin-polarization is generated by an electrical current, which acts with a torque on the magnetisation exciting magnetic dynamics [1]. This relativistic non-equilibrium spin phenomenon also has a reciprocal effect in which the excitation of magnons results in the pumping of a charge current [2].

I will start by reviewing our recent research on spin-orbit torques (SOTs) in crystalline magnets, in particular our very recent measurements of room temperature SOT in half-Heusler NiMnSb thin films. With this experiment we are able to fully characterise magnitude and symmetry of the SOTs [3, 4]. I will then talk about the first demonstration of magnonic charge pumping in crystal magnet GaMnAs [2]. In this effect, which is the reciprocal effect of SOTs, the precessing ferromagnet pumps a charge current. Differently from spin pumping, which is commonly used to electrically detect magnetization dynamics, in charge pumping magnons are converted within the ferromagnet into high-frequency currents via the relativistic spin-orbit interaction, without the need of a secondary spin-charge conversion element, such as heavy metals with large spin Hall angle.

References 1. Chernyshov et al., Nature Physics 5, 656 (2009). 2. Ciccarelli et al., Nature Nano 10, 50 (2014). 3. Fang et al., Nature Nano 6, 413 (2011). 4. Kurebayashi et al., Nature Nano 9, 211 (2014).

15 min. break

MA 30.2 Wed 10:15 H33

Spin-orbit effects in Pt/Co/AlOx as a function of temperature with varying ferromagnetic layer thickness — •Gurucharan V. Karnad[1], Roberto Lo Conte[1,2], K. Lee[1], S. Prenzel[1], T. Schulz[1], N.-H. Kim[3], K. Litzius[1,2], J.-S Kim[4], D.-S. Han[4], H.J.M. Swagten[4], C.-Y. You[3], and M. Kläui[1,2] — [1]Johannes Gutenberg Universität-Mainz, Institut für Physik, Staudinger Weg 7, 55128 Mainz, Deutschland — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), Staudinger Weg 9, 55128 Mainz, Deutschland — [3]Department of Physics, Inha University, Incheon 402-751, South Korea — [4]Department of Applied Physics, Center for NanoMaterials, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands

Material systems possessing perpendicular magnetic anisotropy and structural inversion asymmetry have attracted much attention due to the highly efficient current induced magnetization switching and fast domain wall motion observed in these systems. This has been attributed to spin orbit effects arising at the interface and in the bulk. Here, we report measurements of current induced domain wall motion and spin-orbit torques in Pt/Co(t)/AlOx, with varying thickness of the Co layer. We observe that the Dzyaloshinskii-Moriya interaction (DMI) decreases with increasing Co thickness, pointing to its interfacial origin. The current induced damping-like and field-like torques are also observed to be sensitive to temperature and Co thickness. This allows us to understand the relative contribution of spin-orbit effects originating at the interface and the bulk.

MA 30.3 Wed 10:30 H33

Investigation of Co thickness dependence of current induced domain wall motion in Co/Pt — •Caspar Florin[1], André Kobs[1,2], Carsten Thönnissen[1], Phillip Staeck[1], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Feskörperphysik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

Spin orbit torque phenomena based on spin orbit coupling are in the very focus of present research due to their high potential for future logic and storage devices [1,2]. We present the Co thickness dependence of the spin orbit torque (SOT) in Pt (5nm)/Co (t_{Co})/Pt (3nm) sandwiches with perpendicular magnetic anisotropy at room temperature (0.5nm $\leq t_{\mathrm{Co}} \leq$ 0.9 nm). Utilizing micro-sized Co/Pt wires and current pulses with a duration of $\geq$ 2 ns the domain wall motion is investigated by means of a Kerr microscope. The domain wall velocity is determined as a function of current density and out-of-plane magnetic field in the creep and flow regime. By varying the Co thickness we are able to separate interfacial and volume contributions to the SOT that are caused by Rashba effect and spin Hall effect, respectively.[1] I. M. Miron et al., Nat Mater **9**, 230 (2010). [2] P. P. J. Haazen et al.,Nat Mater, **12**, 299 (2013).

MA 30.4 Wed 10:45 H33

Spin-orbit torques in $L1_0$-FePt/Pt thin films from first principles: effect of impurities — •Guillaume Géranton, Bernd Zimmermann, Frank Freimuth, Nguyen H. Long, Phivos Mavropoulos, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spin-orbit torque (SOT) is an attractive way of manipulating the magnetization in spintronic devices. While the intrinsic contributions to the SOT have been investigated in the last years [1], little is known about the extrinsic contributions, i.e. the torques arising in the presence of impurities. Using the *ab initio* Boltzmann formalism, we compute the current-induced SOT in $L1_0$-FePt/Pt thin films in the presence of impurities. The transition rates between electronic states are obtained from the microscopic scattering rates computed from first principles [2]. This goes significantly beyond the standard description of extrinsic SOTs, which is usually based on the constant relaxation-time approximation [3]. We show the crucial dependence of the SOT on the distribution of impurities at the interface, demonstrate that a large part of the SOT is mediated by spin currents and observe a large spin accumulation in the Pt layers.

We gratefully acknowledge funding under the SPP 1538 programme of DFG.

[1] F. Freimuth et al., Phys. Rev. B **90**, 174423 (2014).
[2] N. H. Long et al., Phys. Rev. B **90**, 064406 (2014).
[3] G. Géranton et al., Phys. Rev. B **91**, 014417 (2015).

MA 30.5 Wed 11:00 H33

Spin transfer torque within the 3D-WKB electron tunneling model — Gabor Mandi[1] and •Krisztian Palotas[1,2] — [1]Budapest University of Technology and Economics, Department of Theoretical Physics, Budapest, Hungary — [2]Slovak Academy of Sciences, Institute of Physics, Bratislava, Slovakia

We introduce a calculation method for a combined description of charge and vector spin transport of tunneling electrons in magnetic scanning tunneling microscopy (STM) within the three-dimensional Wentzel-Kramers-Brillouin (3D-WKB) theory based on electronic structure data from first principles. Taking the Fe/W(110) surface, we show that the ratio between the spin transfer torque (STT) and the spin-polarized charge current is not constant and can be tuned by the bias voltage, tip-sample distance and magnetization rotation. Thus, we demonstrate the possible enhancement of the STT efficiency in magnetic STM junctions. We discuss our results in view of the indirect measurement of STT above the Fe/W(110) surface reported by Krause et al. in Phys. Rev. Lett. 107, 186601 (2011).

MA 30.6 Wed 11:15 H33

Terahertz nonlinear spin response in thulium orthoferrite — •Sebastian Baierl[1], Matthias Hohenleutner[1], Tobias Kampfrath[2], Anatoly Zvezdin[3], Alexey Kimel[4], Rupert Huber[1], and Rostislav Mikhaylovskiy[4] — [1]Department of Physics, University of Regensburg, 93053 Regensburg, Germany — [2]Department of Physical Chemistry, Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin, Germany — [3]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [4]Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, 6525 AJ Nijmegen, the Netherlands

We show the first nonlinear spin response of a magnetically ordered system to intense terahertz (THz) fields. The oscillating carrier wave of ultrashort THz pulses coherently excites magnons in the canted antiferromagnet thulium orthoferrite. In its spin reorientation phase, the amplitude of the quasi-ferromagnetic mode is found to scale quadratically with the THz field, exceeding the strength of the Zeeman interaction by a factor of 7 for peak magnetic THz fields of 0.3 T. This finding marks a new regime of THz-induced spin dynamics beyond the Zeeman interaction and the first observation of a THz field-triggered magnetic nonlinearity. We assign this intriguing effect to an ultrafast, THz electric-field-driven change of the magnetic anisotropy mediated by crystal field transitions within the thulium ions. By symmetry, the latter effect is only allowed if the crystal is situated in the spin reorientation phase. This novel driving mechanism points out unforeseen routes towards THz induced magnetic switching.

15 min. break

MA 30.7 Wed 11:45 H33

Snell's Law for Spin Waves — •Johannes Stigloher[1], Martin Decker[1], Helmut Körner[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]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Department of Physics, Nagoya University, Nagoya, Aichi 464-8602, Japan — [3]Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan — [4]Dipartimento di Fisica e Geologia, Universita di Perugia, I-06123 Perugia, Italy — [5]Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan

Snell's law is well known in optics, it describes the refraction of light at the transition between two transparent media. In contrast to light, spin waves in the dipolar regime have an anisotropic dispersion relation and are expected to behave differently at the transition between two media. In our experiments, we model an interface for spin waves by a thickness step: Spin waves are excited in a 60 nm thick Permalloy film by a microwave antenna and propagate into a 30 nm thick film. Utilizing time-resolved scanning Kerr microscopy we can directly track the wave fronts and therefore deduce the changes in the angle of propagation and in the wave vector amplitude at the transition to the thinner film. By measuring the refraction for varying incident angles, we determine Snell's law for spin waves.

MA 30.8 Wed 12:00 H33

Radiative damping in waveguide-based ferromagnetic resonance measured via analysis of perpendicular standing spin waves in sputtered permalloy films — Martin Schoen[1,2], Justin Shaw[1], Hans Nembach[1], •Mathias Weiler[3], and T.J. Silva[1] — [1]Quantum Electromagnetics Division, National Institute of Standards and Technology, USA — [2]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [3]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, D-85748 Garching, Germany

In ferromagnetic resonance measurements one often neglected contribution to the measured damping is the damping enhancement due to inductive coupling between the precessing magnetization and the waveguide, the radiative damping. We investigate the radiative damping by measuring perpendicular standing spin waves in uniform 75 nm, 120 nm, and 200 nm Ni(80)Fe(20) films with multiple cap and seed layer configurations and compare the measured radiative damping to the one calculated in a simple model. The measurement of spin waves allows us to observe a direct proportionality of the damping enhancement to the spin wave inductance, as predicted by our model. Furthermore we present a method to directly measure radiative damping by decreasing the inductive coupling between sample and wave guide. Though inherently small for thin films (0.0003 for a 10 nm Permalloy film) the radiative damping can be a significant contribution to the total damping in materials with small intrinsic damping or large saturation magnetization, like yttrium-iron-garnett or Co(25)Fe(75).

MA 30.9 Wed 12:15 H33

Spin pumping into high conductivity polymers — •Mohammad Qaid[1], Tim Richter[1], Christoph Hauser[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg,Von-Danckelmann-Platz 3, 06120Halle — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich Damerow Straße 4, 06120 Halle

Conducting polymers seem ideal candidates for application as spin charge converters using the inverse spin-Hall-effect, as they are flexible, easy to apply and can be obtained at low cost. Recently, the ISHE has been demonstrated in poly (3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS) [1]. We have studied spin pumping and ISHE in hybrid structures composed of thin film yttrium-iron garnet (YIG) and PEDOT:PSS of various conductivities which can be varied by doping with high boiling solvents. The spin pumping is studied using the uniform mode of the ferromagnetic resonance but also for different magnon modes which can be excited in the experiment. As we show in our results using PEDOT:PSS leads to additional damping most likely due to spin pumping, however extreme care must be taken to distinguish between the real effects and side effects like damping by eddy currents or thermovoltages which can be much bigger than the inverse spin-Hall effect.

References: [1]- K. Ando, S.Watanabe, S.Mooser, E. Saitoh, and H. Sirringhaus, Nat. Mater. 12, 622 (2013)

MA 30.10 Wed 12:30 H33

Spin-transfer torque based damping control of parametrically excited spin waves in a magnetic insulator — •Viktor Lauer[1], Dmytro A. Bozhko[1,2], Thomas Brächer[1], Philipp Pirro[1], Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], Matthias Benjamin Jungfleisch[1], Milan Agrawal[1], Yurii V. Kobljanskyj[3], Gennadii A. Melkov[3], Carsten Dubs[4], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Material Science in Mainz, Germany — [3]Faculty of Radiophysics, Electronics and Computer Systems, Taras Shevchenko National University of Kyiv, Ukraine — [4]Innovent e.V., Jena, Germany

Our experimental studies address the spin-wave damping control in a macroscopically sized YIG(100nm)/Pt(10nm) bilayer, based on the spin Hall effect (SHE) and spin-transfer torque (STT). The application of a dc current to the Pt film leads to the formation of a spin-polarized electron current normal to the film plane due to the SHE. This spin current exerts a STT in the YIG film and, thus, changes the spin-wave damping. The variation of the spin-wave relaxation frequency is determined via the threshold of the parametric instability measured by Brillouin light scattering (BLS) spectroscopy. We show that depending on the polarity of the applied dc current with respect to the magnetization direction, the damping can be increased or decreased.

This work is financially supported by the EU-FET grant InSpin 612759.

MA 30.11 Wed 12:45 H33

Investigation of spin wave dispersions in Co thin films on W(110) from first-principles — •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

We computed spin wave dispersions of a few monolayers of Co deposited on the W(110) surface in the adiabatic approximation. The magnetic exchange interactions are obtained via first-principles electronic structure calculations using the Korringa-Kohn-Rostoker Green function method. We analyze the strength and oscillatory behavior of the intra-layer and inter-layer magnetic interactions and investigate the resulting dispersion of spin waves as a function of the thickness of Co films. We compare our results to recent measurements [1] based on electron energy loss spectroscopy. In particular, we demonstrate the strong impact of hybridization of the electronic states at the interface of Co and W on the magnetic exchange interactions and on the spin-waves dispersion curve. The distance dependence of the magnetic interactions is found to be strongly anisotropic, which we connect to the presence of quantum well states in the Co films.

Work supported by the Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (BRAZIL) and HGF-YIG Programme FunSiLab - Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717). [1] E. Michel, H. Ibach, and C. M. Schneider, Phys. Rev. B 92, 024407 (2015).

MA 30.12 Wed 13:00 H33

Mixed Berry curvatures from first principles — •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

Both spin-orbit torques (SOT) and Dzyaloshinskii-Moriya interaction (DMI) arise in systems combining broken inversion symmetry and spin-orbit coupling. In a Berry phase theory the two phenomena are intimately related through the mixed Berry curvature which incorporates wave function derivatives with respect to crystal momentum $\boldsymbol{k}$ and magnetization direction $\hat{\boldsymbol{m}}$ [1]. Performing the differentiation with respect to magnetization direction, however, renders the first-principles evaluation of the mixed Berry curvature a conceptually difficult task. Here, we present a scheme that grants efficient but accurate access to general mixed (and pure) Berry curvatures. Starting from the first-principles electronic structure, we employ higher-dimensional Wannier functions (HDWFs) [2] as minimal basis to treat the aforementioned wave function derivatives on an equal footing. We apply our method to Mn/W(001) where we analyze the mixed Berry curvature throughout $(\boldsymbol{k}, \hat{\boldsymbol{m}})$ phase space. Using the Berry phase expressions, we further compute SOT and DMI in the system and study the anisotropy with respect to magnetization direction.

[1] F. Freimuth *et al.*, J. Phys. Condens. Matter **26**, 104202 (2014)
[2] J.-P. Hanke *et al.*, Phys. Rev. B **91**, 184413 (2015)

MA 31: Magnetization and Demagnetization Dynamics II

Time: Wednesday 9:30–12:45 Location: H34

MA 31.1 Wed 9:30 H34

Driving spins in magnetic storage FePt by all optical switching — •Robin John[1], Cai Mueller[2], Dagmara Butkovicova[3], Eva Schmoranzerova[3], Pablo Nieves[4], Tiffany Santos[5], Jakob Walowski[1], Oksana Chubykalo-Fesenko[4], Jeffrey McCord[2], and Markus Muenzenberg[1] — [1]Institute for Physics, Ernst-Moritz-Arndt-University, Greifswald, Germany — [2]Institute for Materials Science, Kiel University, Germany — [3]Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic — [4]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain — [5]San Jose Research Center, HGST, a Western Digital Company, San Jose, USA

Magnetization manipulation is an indispensable tool for both basic and applied research. Following the work of Lambert et al., we investigate the fluence dependence of all-optical switching. In our work we use a Coherent RegA system to write the patterns with a high repetition rate of 250 kHz with a temporal width of 40 fs. We are able to switch deterministically from the demagnetized ground state back and forth using the two circular polarizations of the laser. We have also tried to find the mechanism of magnetization switching upon the interaction with circular femtosecond laser pulses by comparing the contrast profiles (from Kerr microscopy images) with simulations of spatial profile of the electronic temperature of the system within a range of fluences. We had also conducted ultrafast dynamics experiment using Time-Resolved Magneto Optical Kerr set-up by using the two circular polarizations states of the laser to trace the mechanism.

MA 31.2 Wed 9:45 H34

Ultrafast All-Optical Control of Magnetization on the Nano-Scale — •D. Weder[1], C. von Korff Schmising[1], C. M. Günther[2], M. Schneider[1], B. Pfau[3], B. Vodungbo[4], E. Jal[4], J. Lüning[4], F. Capotondi[5], and S. Eisebitt[1] — [1]Max-Born-Institut, 12489 Berlin — [2]Technische Universität Berlin, 10623 Berlin — [3]Lund University, S-22100 Lund — [4]Sorbonne Universités, 75005 Paris — [5]Elettra-Sincrotrone Trieste, 34149 Basovizza, Trieste

All optical control of magnetization is emerging as a general phenomenon in solid state physics applicable to an ever growing number of magnetic systems [1], including high anisotropy ferromagnetic Co/Pt multilayers [2], technological one of the most important class of materials for ultra-high-density magnetic recording. However, to compete with the bit density of conventional storage devices, all-optical magnetic switching applications rely on sub-wavelength spatial confinement of the optical excitation as well as control of non-local phenomena like super-diffusive spin and electron transport. We engineer sub-wavelength spatial localization of the optical excitation with lithographically fabricated proximity masks and induce tailored transient magnetic gratings and arrays. Extreme ultraviolet radiation from a free electron laser (FERMI, Elettra) is used in a combination of resonant magnetic small angle X-ray scattering and Fourier transform holography imaging experiments [3] giving direct access to the ultrafast evolution of the lateral magnetization on a nanometre length scale.

[1]Mangin et al., Nat. Mat., 13, 286 (2014), [2]Lambert et al., Science, 345, 1337 (2014), [3]Korff Schmising et al., PRL, 112, 217203 (2014)

MA 31.3 Wed 10:00 H34

Computer simulations on ultrafast magnetization dynamics in ferrimagnetic $DyCo_5$ — •Andreas Donges[1], Sergii Khmelevskyi[2], Andras Deak[3], Radu-Marius Abrudan[4,5], Florin Radu[4], Ilie Radu[4,6], László Szunyogh[3], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457, Germany — [2]Vienna University of Technology, 1040, Austria — [3]Budapest University of Technology and Economics, 1111, Hungary — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489, Germany — [5]Ruhr-Universität Bochum, 44780 Germany — [6]Technical University Berlin, 10623, Germany

Ferrimagnetic rare earth transition metal alloys have gained a lot of scientific attention, since the seminal work of Radu et al. [1], which showed that the magnetization of such a compound can be switched by a pure thermal excitation. The motivation for our research on $DyCo_5$ is given by a variety of intriguing properties, especially its magnetization compensation point and its spin reorientation transition, where the easy axis changes from the in-plane to the out-of-plane direction [2]. We implemented a multi-scale model, combining ab-initio calculations with an atomistic spin model, to study how this spin reorientation affects magnetization dynamics on the ps and sub-ps time scales. Different dynamics are found, in response to an ultrafast laser excitation, for the in-plane and out-of-plane phases, as well as for the rare earth and transition metal sublattices.

[1] I. Radu, et al., Nature **472**, 205-208 (2011)
[2] T. Tsushima, M. Ohokoshi, JMMM **31-34**, 197-198 (1983)

MA 31.4 Wed 10:15 H34

The role of non-equilibrium hot electrons in ultrafast laser-induced demagnetization — •Ilya Razdolski[1], Alexandr Alekhin[1], Ulrike Martens[2], Markus Münzenberg[2], and Alexey Melnikov[1] — [1]Fritz-Haber-Institut der MPG, Berlin, Germany — [2]Ernst-Moritz-Arndt Universität, Institut für Physik, Greifswald, Germany

Ultrafast demagnetization of thin transition metal films in the absence of the hot carrier transport is studied by time-resolved magneto-optical

Kerr effect (MOKE) with 20 fs resolution for various laser fluences. We demonstrate that the key role in the ultrafast magnetization dynamics is played by the non-equilibrium hot electrons, in line with previous theoretical studies. The demagnetization timescale of about 200 fs is determined by their thermalization due to the electron-electron interaction. The subsequent re-magnetization occurs on 1 ps timescale of the electron-lattice interaction. Further, we suggest an approach for the MOKE experiments which allows for the disentanglement of the magnetization dynamics and optical effects by measuring a complete set of the transient optical response data, including reflectivity, MOKE rotation, and ellipticity.

MA 31.5 Wed 10:30 H34

Light-induced magnetization dynamics in a ferromagnetic Rashba-model — •Christiane Scholl, Svenja Vollmar, and Hans Christian Schneider — TU Kaiserslautern, Department of Physics

We numerically investigate magnetization dynamics in a model system of a (mean-field) Rashba-ferromagnet due to non-resonant polarized optical fields. Electron-electron-scattering processes are taken into consideration by means of a modified relaxation-time approximation. Within the framework of this model, we show in microscopic detail how the magnetization dynamics is determined by the polarization direction of the electric field, which can result in a switching of the magnetization. We compare our results with two different models in the literature: inverse-Faraday effect [1] and spin-selective optical Stark effect [2].

[1] D. Popova, A. Bringer, S. Blügel, Phys. Rev. B 85, 094419 (2012)

[2] A. Qaiumzadeh, G. Bauer, A. Brataas, Phys. Rev. B 88,064416 (2013)

MA 31.6 Wed 10:45 H34

Probing ultrafast spin dynamics of interface induced magnetism in platinum with circular polarized light from high harmonics generation — •Felix Willems[1,2], Christopher Smeenk[2], David Weder[1,2], Nick Zhavoronkov[2], Oleg Kornilov[2], Clemens von Korff Schmising[2], Ilie Radu[2], Marc Vrakking[2], and Stefan Eisebitt[1,2] — [1]IOAP, TU Berlin, Straße des 17.Juni 135, 10623 Berlin — [2]Max-Born-Institut, Max-Born-Straße 2 A, 12489 Berlin

All-optical control and manipulation of magnetization in thin magnetic films is a promising route for spintronic and next-generation magnetic data storage devices [1, 2]. However, progress in understanding and, hence, in the successful design of such new multi-component magnetic systems for ultrafast applications has been challenged by the difficulty to experimentally access the underlying complex microscopic processes. We combine a high harmonic generation source with a $\lambda/4$ phase shifter to obtain circularly polarized XUV fs-pulses. The broad spectral bandwidth spanning 40-70 eV makes simultaneous detection of the element-specific spin dynamics via XMCD absorption spectroscopy possible. This allows us to extract information about individual contributions of the different materials and interacting spin systems. We report on first measurements of a Pt/Co/Pt sample showing simultaneous ultrafast demagnetization of Co and spin polarized Pt at the Co interface after optical excitation [3]. [1] A. Kirilyuk, A. et al., Rep Prog Phys 76, 026501 (2013). [2] S. Mangin, et al., Nature Materials 13, 286 (2014). [3] F. Willems et al., PRB R (in press)

15 min. break

MA 31.7 Wed 11:15 H34

***Ab initio* theory for ultrafast spin dynamics on the magnetic Ni_3 and Co_3^+ clusters, also with adsorbed MeOH and EtOH molecules** — •Georgios Lefkidis[1], Debapriya Chaudhuri[1], Wei Jin[2], and Wolfgang Hübner[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]School of Physics and Information Technology, Shaanxi Normal University, Xi'an, China

We present a systematic study of the laser-induced, ultrafast spin dynamics on the magnetic trimers Ni_3 and Co_3^+. We investigate the clusters both bare and with MeOH and EtOH adsorbed, which induce spin-density localization. The quality of our high-level, correlational quantum-chemistry calculations is assessed by comparing with experimental IR and electronic spectra [1,2].

By employing optical Λ processes [3] we achieve coherent manipulation of the well localized spins on the trimers, giving rise to a cyclic-SHIFT-register magnetic-logic element. Analyzing the different contributions to the total angular momentum during the processes we also perform calculations including the rotational normal modes of the trimers. Finally we calculate the Kerr effect and the tolerance of the mechanisms with respect to the laser pulse parameters.

[1] W. Jin, M. Becherer, D. Bellaire, G. Lefkidis, M. Gerhards, and W. Hübner, PRB **89**, 144409 (2014)

[2] D. Chaudhuri, W. Jin, G. Lefkidis, and W. Hübner, JCP **143**, 174303 (2015)

[3] G. Lefkidis, G. P. Zhang, and W. Hübner, PRL **103**, 217401 (2009)

MA 31.8 Wed 11:30 H34

Unified *ab initio* theory of the inverse Faraday effect — •Marco Berritta[1], Ritwik Mondal[1], Karel Carva[2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Charles University, Prague, Czech Republic

Nowadays, among the rich scenario of magneto-optical phenomena, the inverse Faraday effect (IFE) appears potentially a powerful tool for the control and manipulation of the magnetization of materials. Many studies have been recently performed, however a unifed theoretical interpretation of the IFE is still missing.

On the basis of a general formulation of the second order response to a circularly polarized light pulse [1], which allows to easily include relativistic effects, we perform *ab initio* calculations of the IFE. We present results of calculations for some non-magnetic materials in comparison with results for magnetic materials. We provide a unifed discussion of the relativistic contribution calculated from this theory in comparison to Dirac theory considerations made in [2]. Moreover, although previous theoretical models of the IFE take as an approximation the absence of absorption in materials, we find that absorption can leads to counterintuitive features that can be essential for achieving switching in magnetic materials.

[1] M. Battiato, G. Barbalinardo, and P. M. Oppeneer, Phys. Rev. B **89**, 014413 (2014).

[2] R. Mondal, M. Berritta, C. Paillard, S. Singh, B. Dkhil, P. M. Oppeneer, and L. Bellaiche, Phys. Rev. B **92**, 100402 (2015).

MA 31.9 Wed 11:45 H34

Time- and Spin-resolved Photoemission Study of the Ultrafast Demagnetization Process in thin Co Films using High-order Harmonic Generation — •Moritz Plötzing[1], Markus Rollinger[2], Steffen Eich[2], Sebastian Emmerich[2], Roman Adam[1], Cong Chen[3], Henry Kapteyn[3], Margaret Murnane[3], Lucasz Plucinski[1], Benjamin Stadtmüller[2], Mirko Cinchetti[2], Martin Aeschlimann[2], Claus Schneider[1], and Stefan Mathias[4] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Insitut 6, 52425 Jülich, Germany — [2]TU Kaiserslautern and Research Center OPTIMAS, 67663 Kaiserslautern, Germany — [3]JILA, University of Colorado and NIST, Boulder, Colorado 80309-0440, USA — [4]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany

A powerful experimental technique that promises to provide novel information on the ultrafast demagnetization mechanisms is the direct mapping of the time evolution of the electronic band structure using spin-resolved photoelectron spectroscopy. Our approach combines a bright, femtosecond pulsed extreme ultraviolet (XUV) light source optimized for photoemission with a state-of-the-art spin detector and allows a direct, energy-resolved observation of the electron- and spin-dynamics over the full valence bands of 3d-ferromagnets after optical excitation. We present our experimental setup as well as results of the laser-induced, ultrafast demagnetization in thin Co films. Moreover, we discuss possible underlying mechanisms, e.g. a reduction of the exchange splitting or a spin-mixing, on the basis of our observations.

MA 31.10 Wed 12:00 H34

Magnetic moment of inertia tensor from first principles — •Danny Thonig, Manuel Pereiro, and Olle Eriksson — Department of Material Theory, Uppsala University, Sweden

The evolution of atomic magnetic moments is well described in terms of precession and a damping for the adiabatic limit. Approaching the adiabatic limit, however, turned out to extend the Landau-Lifshitz-Gilbert equation by an inertia contribution [1]. Magnetic inertia ι is the resistance of the magnetic moment to relax, e.g. in ultra fast switching by an external magnetic field [2], that — to the best of our knowledge — have not been characterized on an ab initio basis.

We deduce the moment of inertia tensor from the breathing band model [3] and apply it in the framework of a renormalized Green function tight-binding approach. Slater-Koster parameters were obtained by a genetic-algorithm and Monte Carlo optimization with respect to first-principles results. Our model reveals that the moment of inertia tensor ι_{ij} is non-local and temperature dependent.

Our approach is applied to the bulk Stoner magnets and could be compared to recent experimental measurements [4]. Supported by atomistic magnetization dynamics simulations we reveal the importance of magnetic inertia in ultrafast relaxation processes.

[1] M.-C. Ciornei et al., Phys. Rev. B 83, 020410 (2011).
[2] D. Böttcher et al., Phys. Rev. B 86, 020404(R) (2012)
[3] V. Kamberský, Cz. Journal of Physics B 34, 1111 (1984)
[4] Y. Li et al., Phys. Rev. B 92, 140413(R) (2015)

MA 31.11 Wed 12:15 H34

Ultrafast magnetization dynamics in a spin-orbit coupled ferromagnetic system due to microscopical electron-phonon-scattering — •Kai Leckron[1], Svenja Vollmar[1,2], and Hans Christian Schneider[1] — [1]University of Kaiserslautern — [2]Graduate School of Excellence Materials Science in Mainz

We investigate the (de)magnetization dynamics due to electron-phonon scattering in a ferromagnetic Rashba model. We calculate the electronic spin-density matrix and explicitly show that the incoherent scattering due the electrostatic electron-phonon interaction, which is sometimes called the Elliott contribution to the Elliott-Yafet mechanism, does not lead to spin dynamics. We further analyze the influence of the other contributions to spin dynamics: the spin-dependent electron-phonon interaction and the coherent dynamics of off-diagonal elements of the spin-density matrix.

MA 31.12 Wed 12:30 H34

Nonequilibrium magnetization dynamics beyond the three temperature model — •Karel Carva[1], Pavel Balaz[1], Peter Oppeneer[2], and Pablo Maldonado[2] — [1]Charles University in Prague, DCMP, Ke Karlovu 5, CZ-12116, Prague, Czech Republic — [2]Uppsala University, PO Box 516, 75120 Uppsala, Sweden

Femtosecond magnetization dynamics has been commonly described employing the three temperature model, without verifying its validity. We show when it fails to describe correctly the specific subsystems.

For Gd metal we calculate from first principles exchange interaction between atomic moments, as well as the intra-atomic exchange between Gd 4f and 5d orbitals. Spin dynamics solution of the corresponding effective orbital-resolved Heisenberg Hamiltonian has shown disparate magnetization dynamics of the 4f and 5d moments, in a good agreement with the experiment [1]. The magnetic state here cannot be assigned one temperature for times up to 100 ps.

In order to study lattice behavior we calculate the electron-phonon scattering rates for systems with high electronic temperature [2], and phonon lifetimes due to phonon-phonon scattering. From this we obtain phonon population that differs sharply from the thermal one within picoseconds after the pump. This allows to understand recent experimental observations and disproves the applicability of the model based on one lattice temperature here [3].

1. Frietsch, B. et al. , Nat Commun 6, 8262 (2015).
2. Carva, K. et al., Phys. Rev. B 87, 184425 (2013).
3. Henighan T. et al., arXiv: 1509.03348

MA 32: Scanning Probe Microsocopy and Spin Phenomena

Time: Wednesday 15:00–17:00 Location: H4

Invited Talk MA 32.1 Wed 15:00 H4

Spin-orbit coupling, magnetic perturbations, and competing trends in topological insulators — •Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Topological insulators (TIs) interacting with magnetic perturbations lead to several unconventional effects, usually described within the framework of gapping the Dirac quasiparticles due to broken time-reversal symmetry [1,2]. While the quantum anomalous Hall effect confirmes the presence of ferromagnetically gapped Dirac states, the overwhelming majority of photoemission and tunneling data demonstrate the presence of a finite density of states at the Dirac point even once the system becomes magnetic. We present a series of experiments which, by mapping the response of TIs to different magnetic impurities down to the atomic level, provide a detailed microscopic picture and thereby solve these contradictory observations in both surface- and bulk-doped samples. We provide evidence of highly anisotropic Dirac fermion-meditated magnetic interactions that lead to quantum coherent states propagating over mesoscopic distances. We also show that magnetic order and gapless states can coexist due to the emergence of a two-fluid behavior where the competition in between opposite trends, i.e. gap-opening vs. gap-closing, is ultimately linked to the localized vs. delocalized nature of the perturbations-induced quasiparticles.

[1] P. Sessi et al., Phys. Rev. B 88, 161407 (2013).
[2] P. Sessi et al., Nature Comm. 5, 5349 (2014).

Invited Talk MA 32.2 Wed 15:30 H4

Conductance and shot noise spectroscopy of single magnetic atoms and molecules — •Alexander Weismann — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel

The scanning tunneling microscope allows to build and study nanostructures at a single atom level. It can be further used to explore the ballistic electron transport regime by bringing the tip into contact with single atoms and molecules in a well-defined way. The measurement of quantum shot noise in nanoscopic contacts provides additional information on the underlying conduction processes and reveals a spin polarization of the current by single Fe and Co atoms between two gold electrodes. The impact of spin-orbit coupling on electron transport is demonstrated using single Ir atoms on a ferromagnetic substrate, where large changes of the anisotropic magnetoresistance occur between the tunneling and the contact regime. On retinoic acid, a closed-shell organic bio-molecules comprising only C, H and O atoms, the STM can be used to reversibly switch the spin state, which is attributed to the conversion into a radical cation.

Invited Talk MA 32.3 Wed 16:00 H4

Manipulating spins in single molecules on a superconductor — •Benjamin W. Heinrich — Freie Universität Berlin, Fachbereich Physik, Berlin

The dominant relaxation mechanism for excited spin states on a metal is the exchange of energy and angular momentum with conduction electrons, which results in the creation of electron-hole pairs. A commune strategy to increase the spin lifetime consists in reducing the exchange scattering by the introduction of a thin insulating layer between adsorbate and substrate. We propose an alternative route to stabilize excited spin states, which is based on combining a metal-organic complex with a type I superconductor. The organic ligand decreases the exchange scattering with the superconducting quasiparticles sufficiently to avoid screening. In turn, the superconducting gap prohibits the energy transfer to electron-hole pairs when the excitation energy is smaller than the gap. This increases the excitation lifetime for Fe-octaethylporphyrin-chloride to 10 ns when adsorbed on a superconducting lead substrate, which is orders of magnitude longer than when adsorbed on a metal.

Our strategy will enable even longer lifetimes, perhaps sufficiently long to enable coherent spin manipulation, for systems with a well-chosen anisotropy barrier. It turns out that metal-organic complexes might be suited to achieve this goal. They provide structural flexibility such that the ligand field can be reversibly modified by local potentials, *e.g.*, the tip of the STM, which then modifies the magnetic anisotropy. Fine-tuning of the anisotropy appears to be within reach.

MA 32.4 Wed 16:30 H4

Voltage-dependent rotational motion of Phthalocyanine molecules — •Andreas Krönlein, Jens Kügel, Paolo Sessi, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, 97074 Würzburg, Germany

Single particle manipulation offers unique possibilities to tune the electronic properties of molecular and atomic assemblies and thereby opens new pathways for future electronic devices. Therefore, the understanding of the underlying physical mechanisms is of significant importance. We have performed STM/STS measurements of single transition metal phthalocyanine (*TM*Pcs) molecules adsorbed on van der Waals surfaces. We find a voltage-dependent rotational movement threshold which coincidence with the energy of the lowest unoccupied molecular orbital (LUMO) [1] of the investigated molecules as determined by STS. Spatially resolved measurements reveal a good match between the spatial distribution of the rotational frequency and the LUMO conductance, indicating its strong involvement. We speculate that the rotational motion is, like in other molecules [2,3], a consequence of vibrational modes excited by the relaxation of electrons tunneling into the LUMO. Besides the acquisition of information correlated to the manipulation of *TM*Pc on van der Waals surfaces this technique provides an additional approach for energetically and spatially mapping the LUMO of rotationally unstable systems.

[1] A. Nickel *et al.*, ACS Nano **7**, 191 (2013).
[2] A. J. Mayne *et al.*, Chem. Rev. **106**, 4355 (2006).
[3] B. C. Stipe *et al.*, Phys. Rev. Lett. **81**, 1263 (1998).

MA 32.5 Wed 16:45 H4

DFT Simulation of AFM-images of Fe, Cu and Si adatoms on Cu(111): different tip models — •Svitlana Polesya[1], Sergiy Mankovskyy[1], Hubert Ebert[1], and Franz Giessibl[2] — [1]Universität München, Department Chemie, Butenandtstr. 5-13, D-81377 München, Germany — [2]Institut für Experimentelle Phzsik, Univ. Regensburg, Germany

Atomic Force Microscopy (AFM) images for Fe, Cu and Si adatoms in there equilibrium positions on Cu(111) surface have been simulated on the basis of Density Functional Theory (DFT). We focus in the present work on the effect of different types of tips on the AFM image. For that reason, the forces experienced by the tip have been calculated for three tip models: single H atom, CO molecule and Cu_4 cluster. The calculated forces for the CO molecule tip fully reproduce the experimentally observed distance dependence of the force profile for a Cu adatom. Also the three fold symmetry of the lateral AFM-image for a Fe adatom, in contrast to a Cu adatom, can be explained using the results of the calculations. The nature of the repulsive forces at large lateral distances from the adatom position (∼ 200-250 pm) is discussed on the basis of the electron density redistribution in the tip-adatom region.

MA 33: Surface Magnetism II (jointly with O)

Time: Wednesday 15:00–17:30 Location: H31

MA 33.1 Wed 15:00 H31

Nanoscale and proximity effects on low-dimensional helical magnetic structures — •Jeison A. Fischer, Leonid M. Sandratskii, Soo-hyon Phark, Safia Ouazi, Dirk Sander, and Stuart Parkin — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

The finite size of nanoscale magnetic structures with non-collinear spin order influences strongly their magnetic state. Also, the proximity to a ferromagnetic material affects the nanoscale spin-order [1]. We combine symmetry arguments, first-principles calculations and spin-resolved scanning tunneling spectroscopy at 10 K and in magnetic fields to study an 1D helical magnet of some nm extension in proximity to both ferromagnetic Co and vacuum regions. We report a non-uniform distortion of the spin helix in an Fe bilayer on Cu(111)[1], where the spin orientation deviates from that of an ideal helical structure. The proximity to either Co or vacuum leads to distortions of the spin orientation within nm range of the respective interface. The distortions give rise to specific energy and position dependent modifications of the spin-resolved electronic density of states. These effects have not been discussed before. We demonstrate that, in contrast to an ideal helix of infinite length, the lack of symmetry of the nm-long distorted Fe spin helix, induces an energy dependence in STS of the magnetization of the differential tunneling conductance at tip position.

[1] Phark, S. H.; Fischer, J. A.; Corbetta, M.; Sander, D.; Nakamura, K. & Kirschner, J. Reduced-dimensionality-induced helimagnetism in iron nanoislands Nat. Commun. 5 (2014) 5183.

MA 33.2 Wed 15:15 H31

Collective magnetism in a hybrid magnetic-superconducting system: Co aggregates on Pb — •Jeison A. Fischer, Srijan S. Saha, Régis Decker, Michael Caminale, Hirofumi Oka, Dirk Sander, Valeri Stepaniuk, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Combining the quantum phenomena superconductivity and magnetism on the nanoscale opens the path towards the exploitation of new types of electronic excitations, such as Majorana end-states [1]. These phenomena rest on the presence of magnetism in nanoscale hybrid magnetic-superconducting systems. Here, we present a combined experimental low-temperature scanning tunneling spectroscopy (STS) and theoretical first-principles study, which surprisingly finds no evidence for a sizable magnetic moment in Co monomers on a Pb surface. When some ten Co atoms aggregate together, we observe by STS at 1.8 K the appearance of additional peaks in the superconducting gap at ± 1.8 meV. These intragap states are hallmarks of the interaction of magnetic moments with a superconductor. Ab initio calculations reveal that structural relaxation of the Co adatom towards the Pb is the physical origin behind the suppression of the magnetic moment of the adatom. The resulting strong hybridization between Co and Pb leads to a balanced spin-split density of states of Co. In contrast, the Co aggregate binds farther above Pb, and a strong inter-atomic interaction within the Co aggregate leads to a conserved magnetic moment.

[1] R. M. Lutchyn et al. Phys. Rev. Lett. 105, 077001 (2010); S. Nadj-Perge et al. Science 346, 602 (2014).

MA 33.3 Wed 15:30 H31

Magnetic Properties of Hybrid Organic-Ferromagnetic Interfaces — •Nicolae Atodiresei, Vasile Caciuc, Rico Friedrich, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Engineering the functionalities in organic spintronic devices requires a reliable description of the electronic properties of the hybrid interface formed by the adsorption of carbon-based materials on magnetic surfaces. The density functional theory provides a framework with predictive power and realistic description of these organic-magnetic hybrid systems. We will present first-principles calculations that demonstrate how the subtle interplay between the chemical, electrostatic and the weak van der Waals adsorption mechanisms determines the geometry, electronic and magnetic structure of such hybrid interfaces. These theoretical studies provide the basic insights required to understand the surface-science experiments and are a key tool to design hybrid interfaces with specific magnetic properties that can be tuned by an appropriate choice of the organic material and magnetic surface. [1] K. V. Raman *et al.*, Nature **493**, 509 (2013); [2] M. Callsen *et al.*, Phys. Rev. Lett. **111**, 106805 (2013). [3] N. Atodiresei et al., MRS Bulletin 39, 596 (2014). [4] J. Brede et al., Nat. Nanotech. 9, 1018 (2014).

MA 33.4 Wed 15:45 H31

Spin-hybridization between molecule and metal at room temperature through interlayer exchange coupling — •Manuel Gruber[1,2,3], Fatima Ibrahim[1], Samy Boukari[1], Loïc Joly[1], Wulf Wulfhekel[2], Fabrice Scheurer[1], Eric Beaurepaire[1], Mebarek Alouani[1], Wolfgang Weber[1], and Martin Bowen[1] — [1]IPCMS, CNRS-UdS, Strasbourg, France — [2]Karlsruher Institut für Technologie, Germany — [3]IEAP, CAU Kiel, Germany

Strong coupling may exist between paramagnetic molecules and a ferromagnetic substrate. However, the study of such hybrid interfaces was so far limited to sublimable molecules deposited in ultra-high vacuum conditions in order to prevent the oxidation of the FM substrate. Here we investigated the possibility to use interlayer exchange coupling as the mediator of the molecule/FM magnetic coupling. Using X-ray magnetic circular dichroism (XMCD), we studied the magnetic coupling between manganese phthalocyanine (MnPc) molecules and a Cu(001)/Co FM substrate separated by a wedge-shaped Cu spacer. The XMCD data show that the Mn ion within MnPc molecules can be magnetically coupled to the Co substrate at room temperature when separated by up to 4 ML of Cu. The XMCD intensity evolves in an oscillatory manner with increasing Cu thickness. By decreasing the temperature, we could observe stronger oscillations in the magnetic coupling and this over a much larger Cu thickness range (up to 12

ML). The phase and the periods of the oscillatory coupling is found to be in agreement with interlayer-exchange-coupling theory [1].

[1] Gruber et al., Nano letters, DOI:10.1021/acs.nanolett.5b02961

MA 33.5 Wed 16:00 H31

Exchange bias and room temperature magnetic order in molecular layers — •Manuel Gruber[1,2,3], Fatima Ibrahim[1], Samy Boukari[1], Hironari Isshiki[2], Loïc Joly[1], Wulf Wulfhekel[2], Fabrice Scheurer[1], Wolfgang Weber[1], Mebarek Alouani[1], Eric Beaurepaire[1], and Martin Bowen[1] — [1]IPCMS, CNRS-UdS, Strasbourg, France — [2]PI, Karlsruher Institut für Technologie, Germany — [3]IEAP, CAU Kiel, Germany

Considerable attention was focused at the interface between a ferromagnet and an organic molecular layer, where promising spintronic properties appear. Separately, molecular semiconductor may exhibit antiferromagnetic (AF) correlations well below RT. Yet, surprisingly, while magnetic pinning of a FM layer through exchange bias with an AF layer constitutes a cornerstone of spintronics, this ingredient remains missing in molecular spintronics. We performed X-ray magnetic circular dichroism measurements on paramagnetic manganese-phthalocyanine (MnPc) molecules deposited onto a FM Co(001) surface. The measurements, in combination with ab initio calculations, show that the Co/MnPc spinterface stabilizes an AF ordering at room temperature within subsequent MnPc monolayers away from the interface. In turn, we studied the impact of the AF MnPc layer on the Co substrate using the magneto-optic Kerr effect: the molecular AF layer magnetically pins the underlying Co film at temperatures below 100 K [1].

[1] Gruber et al., Nat. Mater. 14, 981 (2015)

15 min. break

MA 33.6 Wed 16:30 H31

New approach to determine the microscopic interatomic Dzyaloshinskii-Moriya parameters from DFT calculations — •Markus Hoffmann, Bernd Zimmermann, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

The Dzyaloshinskii-Moriya interaction (DMI) is the key ingredient for the formation of so-called chiral magnetic skyrmions – topological magnetization solitons – in materials with broken structure inversion symmetry. Realistic extended Heisenberg Hamiltonians obtained from a mapping of density functional theory (DFT) calculations provide theoretical insight into the DMI and are the starting point for the investigation of the thermodynamics and spin-dynamics of skyrmions in real chiral magnets. Sofar most DFT calculations provided either micromagnetic DM-vectors or microscopic DM-vectors but of limited interaction range between the magnetic atoms. This prohibits for example the analysis of frustration in the DMI or the consequence of Fermi surface nesting on the DMI. Here, we present a generalization of the derivation of interatomic exchange interactions in ferromagnets [1] to the interatomic DMI in chiral magnets. Applying the magnetic force theorem in a spin-spiral state and calculating $\vec{D}(\vec{q})$ in the full Brillouin zone, the DMI vectors $\vec{D}_{ij}$ can be found via Fourier transformation. We present the analytical expressions relating $\vec{D}_{ij}$ to the single-particle energies and apply our new approach to 2Fe/W(110), a commonly studied system in the field of surface magnetism.

[1] M. Ležaić *et al.*, Phys. Rev. B **88**, 134403 (2013).

MA 33.7 Wed 16:45 H31

Spin Excitation Spectroscopy on Fe4 Molecular Magnets Compressed in the Junction of a Scanning Tunneling Microscopy — •Jacob Burgess[1,2], Luigi Malavolti[1,2,3], Valeria Lanzilotto[3], Matteo Mannini[3], Shichao Yan[1,2], Silviya Ninova[3], Federico Totti[3], Steffen Rolf-Pissarczyk[1,2], Andrea Cornia[4], Roberta Sessoli[3], and Sebastian Loth[1,2] — [1]Max-Planck Institut für Struktur und Dynamik der Materie — [2]Max-Planck Institut für Festkörperforschung — [3]Department of Chemistry Ugo Schiff, University of Florence & INSTM RU of Florence — [4]Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia & INSTM RU of Modena and Reggio Emilia

Here we present inelastic tunneling spectroscopy measurements on individual Fe4 single magnetic molecules. Magnetic excitations at meV energies can be detected. Strong tip interactions are inherent in the measurement and present an experimental challenge. This necessitates the use of a correlation between excitation energy and general topography to identify intact molecules. The spectra of intact molecules indicate that the intramolecular exchange interaction is boosted significantly when compared to bulk molecular crystals. Ab initio calculations show that this can be explained by a minimal tip induced compression of the molecular core[1]. Fe4 remains suitable for spintronics applications when incorporated into prototype device and may have its magnetic properties tuned by mechanical interactions.

[1] J.A.J. Burgess et al., Nature Communications 6, 8216 (2015).

MA 33.8 Wed 17:00 H31

Orienting the magnetic easy axes of molecular single-ion magnets by a graphene interlayer — •Jan Dreiser[1,2], Giulia E. Pacchioni[2], Fabio Donati[2], Luca Gragnaniello[2], Alberto Cavallin[2], Kasper S. Pedersen[3], Jesper Bendix[4], Bernard Delley[5], Marina Pivetta[2], Stefano Rusponi[2], and Harald Brune[2] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI — [2]Laboratory of Nanostructures on Surfaces, Ecole Polytechnique Federale de Lausanne, CH-1015 Lausanne — [3]CNRS, CRPP, UPR 8641, F-33600 Pessac and CNRS, ICMCB, UPR 9014, F-33600 Pessac — [4]Department of Chemistry, Copenhagen University, DK-2100 Copenhagen — [5]Condensed Matter Theory, Paul Scherrer Institut, CH-5232 Villigen

Molecular single-ion magnets (SIMs) [1] are attractive for spintronics applications because of the quantum nature of their spin and the long magnetization lifetimes. We have studied Er(trensal) SIMs [2] adsorbed on graphene/Ru(0001), graphene/Ir(111) and on bare Ru(0001) by scanning tunneling microscopy and x-ray magnetic circular dichroism. On graphene the molecules self-assemble into a densely packed layer with their magnetic easy axes oriented perpendicular to the surface. In contrast, on bare Ru(0001) the molecules are disordered and exhibit different orientations of the easy axes. The graphene-substrate moiré pattern which exhibits a stronger periodic corrugation on Ru(0001) than on Ir(111) does not influence the adsorption and magnetic properties of the molecules. [1] J. Dreiser, J. Phys.: Condens. Matter 27, 183203 (2015). [2] K. S. Pedersen et al., Chem. Sci. 5, 1650 (2014).

MA 33.9 Wed 17:15 H31

Monte Carlo study of chiral magnetic structures in transition-metal multilayers — •Marie Böttcher, Bertrand Dupé, and Stefan Heinze — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24118 Kiel, Germany

Due to their unique topological and dynamical properties and hence the possible application in data storage devices [1], chiral magnetic structures, such as skyrmions, have recently received a lot of interest. One of the main challenges is the stabilization of skyrmions at room temperature. To study the temperature dependence, we performed parallel tempering Monte Carlo (MC) [2] simulations. The advantage of this method is the possibility to overcome local energy minima via temperature and sample large volumes of the phase space. In order to increase the critical temperature of skyrmion systems, we explore transition-metal multilayers built from a repetition of atomic and biatomic layers of Pd, Fe and Ir [3]. We show that the critical temperature in these systems can be significantly enhanced by the interlayer exchange coupling between adjacent Fe bilayers in the multilayer structure. An increase of the exchange coupling in multilayers which may be achieved, e.g. by varying the number or species of 4d or 5d layers within the multilayer, may even yield critical values close to room temperature.

[1] A. Fert *et al.*, Nature Nanotechnology **8** (2013). [2] K. Hukushima and K. Nemoto, J. Phys. Soc. Japan **65** (1996). [3] B. Dupé *et al.*, arXiv:1503.08098 (2015).

MA 34: Topological Insulators (jointly with DS, HL, O, TT)

Time: Wednesday 15:00–17:45 Location: H32

MA 34.1 Wed 15:00 H32

Bulk and surface properties of topological insulators from *GW* calculations. — •Irene Aguilera, Christoph Friedrich, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany.

Many-body calculations within the *GW* approximation are attracting much attention in the study of topological insulators (TIs). They have shown to be critical both in the one-shot approach [1] (e.g. for the Bi_2Se_3 family) and in a quasiparticle self-consistent (QS) *GW* method [2] (e.g. for Bi). In both cases, the spin-orbit coupling has to be incorporated directly into the *GW* self-energy [3]. Within the all-electron FLAPW formalism, we have performed DFT, one-shot *GW*, and QS*GW* calculations for well-known TIs. These calculations are very demanding for low-dimensional systems. Therefore, we construct a tight-binding Hamiltonian for the description of topological surface states in a slab geometry. The corresponding parameters are deduced from *GW* calculations of the bulk. With this approach, we discuss the effects of quasiparticle corrections on the surface states of TIs and on the interaction between bulk and surface states. We show that the *GW* bulk and surface band structure agrees better to results from photoemission experiments than the DFT one. [1] Phys. Rev. B 87, 121111(R) (2013). [2] *Ibid* 91, 125129 (2015). [3] *Ibid* 88, 165136 (2013).

We acknowledge the Virtual Institute for Topological Insulators of the Helmholtz Association.

MA 34.2 Wed 15:15 H32

Magnetic Properties of Mn-doped Bi_2Se_3 and Bi_2Te_3: Ab Initio and Atomistic Simulations — •Pavel Baláž[1], Karel Carva[1], Róbert Tarasenko[1], Vladimír Tkáč[1], Jan Honolka[2], and Josef Kudrnovský[2] — [1]DCMP, Charles University, Ke Karlovu 5, CZ-12116 Prague 2, Czech Republic — [2]Institute of Physics, ASCR, Na Slovance 2, CZ-18221 Prague 8, Czech Republic

Ferromagnetic Curie temperature and other magnetic magnetic properties of bulk Mn-doped Bi_2Se_3 and Bi_2Te_3 3D topological insulators are systematically studied by means of atomistic Monte Carlo simulations. Exchange interactions between the Mn magnetic moments have been calculated using ab initio methods. Tight-binding linear muffin-tin orbital method has been employed, together with the coherent potential approximation to describe the high degree of disorder in the system. Spin-orbit interaction is included in the ground state calculation. In the studied materials Mn atoms might either replace a Bi atom (substitutional position) or fill an empty position in van Der Waals gap between the atomic layers (substitutional position). It has been shown that exchange interaction between Mn magnetic moments might lead to a ferromagnetic phase transition. The Curie temperature is shown to be significantly dependent on the concentration of Mn atoms in substitutional and interstitial positions. Theoretical results were compared to recent experimental studies [1].

[1] R. Tarasenko et al., to be published in Physica B: Phys. Cond. Mat., DOI: 10.1016/j.physb.2015.11.022

MA 34.3 Wed 15:30 H32

Transport measurements on ferromagnet / Half Heusler TI bilayer structures — •Benedikt Ernst[1], Robin Klett[2], Jan Haskenhoff[2], James Taylor[3], Yong Pu[3], Günter Reiss[2], Stuard S. P. Parkin[3], and Claudia Felser[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden — [2]Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld — [3]Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle

Heusler compounds exhibit a manifold of physical properties and attracted in the recent past a lot of interest in the field of spintronic applications due to their half-metallic properties.

In the present work bilayer systems of ferromagnetic materials and half Heusler topological insulators (TI) are studied. The systems were deposited using DC- and RF magnetron co-sputtering. The samples were characterized by X-ray diffraction and electron microscopy techniques. On fabricated devices, the transport properties and spin properties were studied by different measurement techniques including ST-FMR and spin injection experiments.

Additional measurements of the unidirectional spin Hall magnetoresistance were realized. In this effect, we measure a change in the magnetoresistance depending on the direction of the magnetization, which is proportional to the spin Hall angle. We varied the combination of different ferromagnetic materials with different Tis of the YPtBi, YPdBi, LaPtBi and LaPdBi system, and the thicknesses of the layers, to investigate the effects on the transport properties.

MA 34.4 Wed 15:45 H32

Surface preparation and momentum microscopy of the „topological Kondo insulator“ SmB_6 — •Christian Tusche[1,2], Martin Ellguth[1], Fumitoshi Iga[3], and Shigemasa Suga[2,4] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [2]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany — [3]College of Science, Ibaraki University, Japan — [4]Institute of Scientific and Industrial Research, Osaka University, Osaka, Japan

The strongly correlated rare-earth compound SmB_6 is believed to be a topological Kondo insulator, where a topologically non-trivial surface state lives in the hybridization gap at low temperatures. While most experimental studies rely on cleaved surfaces, high resolution- and spin resolved photoemission experiments [1] usually suffer from the short live time of the reactive surface at low temperatures.

Here we present the reproducible surface preparation of large high quality SmB_6 single crystals by in-situ Ar-ion sputtering and controlled annealing. In particular, Sm-rich or B-rich surface terminations are obtained by low (≈1080°C) or high (>1200°C) temperature annealing. Using a momentum microscope [2], wide wave vector regions are studied by photoemission with He-I ($h\nu$=21.2 eV) and laser ($h\nu$=6.0 eV) excitations, on the Sm-terminated surface. The results reveal localized f-electron resonances at E_F and strong hybridization, paving the way to measure detailed Fermi surface and valence band spin textures.

[1] Suga et al., J., Phys. Soc. Japan 83, 014705 (2014)
[2] C. Tusche, A. Krasyuk, J. Kirschner, Ultramicroscopy (2015)

MA 34.5 Wed 16:00 H32

Spin control in the topological surface state of SnTe — •Nicolas Klier[1], Sam Shallcross[1], Sangeeta Sharma[2], and Oleg Pankratov[1] — [1]Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7-B2, 91058 Erlangen — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

The interface of SnTe with a vacuum results in a topological Dirac surface state [1,2]. Based on an effective Hamiltonian derived from tight-binding we investigate the properties of this surface state both with and without an in-plane electric current. The RKKY interaction is found to be strongly non-collinear due to the spin texture of the Dirac state. In the presence of an in-plane current we find (i) a polarization of the surface state and (ii) that the RKKY interaction is strongly modified by the presence of a current leading to a possible "topological spin torque effect".

[1] B.A. Volkov, and O.A. Pankratov, Zh.Eksp. Theor. Fiz. 75, 1362, 1978.
[2] B.A. Volkov, and O.A. Pankratov, JETP Lett.42, 178, 1985.

15 min. break

MA 34.6 Wed 16:30 H32

Adiabatic Pumping of Chern-Simons Axion Coupling — •Maryam Taherinejad[1] and David Vanderbilt[2] — [1]Materials Theory, ETH Zurich, Wolfgang-Pauli-Strasse 27, 8093 Zurich, Switzerland — [2]Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854-0849, USA

The Chern-Simons axion (CSA) coupling θ makes a contribution of topological origin to the magnetoelectric response of insulating materials. Here we study the adiabatic pumping of the CSA coupling along a parametric loop characterized by a non-zero second Chern number $C^{(2)}$ from the viewpoint of the hybrid Wannier representation. The hybrid Wannier charge centers (WCCs), when plotted over the 2D projected Brillouin zone, were previously shown to give an insightful visualization of the topological character of a 3D insulator. By defining Berry connections and curvatures on these WCC sheets, we derive a new formula for θ, emphasizing that it is naturally decomposed into a topological Berry-curvature dipole term and a nontopological

correction term. By explicit calculations on a model tight-binding Hamiltonian, we show how the Berry curvature on the WCC sheets is transported by a lattice vector via a series of Dirac sheet-touching events, resulting in the pumping of e^2/h units of CSA coupling during one closed cycle. The new formulation may provide a particularly efficient means of computing the CSA coupling θ in practice, since there is no need to establish a smooth gauge in the 3D Brillouin zone.

MA 34.7 Wed 16:45 H32

Accessing the transport limits of topological states — •Thomas Bathon[1], Paolo Sessi[1], Konstantin Kokh[2], Oleg Tereshchenko[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Novosibirsk State University, 630090 Novosibirsk, Russia

Topological insulators host on their surface spin-momentum locked Dirac states. Beyond their fundamental interest, these materials raised great expectations to create new functionalities in spintronics and magneto-electrics. Their success depends on our understanding of their response to Coulomb perturbations such as electric fields, which can be effectively used to gate their surface. These phenomena have so far been primarily explored by spatially averaging techniques.

Here, by using scanning tunneling microscopy and spectroscopy, we visualize the response of topological states to local charges and electric fields at the nanoscale. We demonstrate that, contrary to the general believe, local electric fields can not be effectively screened by topological states, but penetrate into the bulk indicating a behavior which is far from being metallic. The analysis of our data allows to detect the existence of a finite conductivity which, because of the local character of our measurements, can be safely quantified without being affected by sample inhomogeinities. Finally, we will show how, by taking advantage of this intrinsic limitation, a new approach to tune both charge and spin transport in this fascinating class of materials can be explored.

MA 34.8 Wed 17:00 H32

Interplay between warping and magnetic effects in Fe monolayer on Sb2Te3 — •Farideh Hajiheidari[1], Wei Zhang[1,2], and Riccardo Mazzarello[1,3] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen University, D-52074 Aachen, Germany — [2]Center for Advancing Materials Performance from the Nanoscale, State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an 710049, PR China — [3]JARA-FIT and JARA-HPC, RWTH Aachen University, D-52074 Aachen, Germany

Three-dimensional topological insulators (TIs) realize an unconventional electronic phase originating from time-reversal symmetry and strong spin-orbit interaction (SOI). These materials are bulk insulators but possess conducting surface states in the bulk band gap. The surface states are topologically protected against non-magnetic disorder. However, impurities which break time-reversal symmetry induce a band gap in the system. This is of critical importance for potential device applications involving spin-based transport. In this work, we present a density-functional-theory study of the magnetic properties of a Fe monolayer on the (111) surface of the topological insulator Sb2Te3. We optimize the geometry of the system and determine the band structure and the easy axis of magnetization for the Fe atoms. We show that the easy axis is in-plane. In spite of this, the presence of the monolayer leads due to the opening of a gap of the order of meV, due to the interplay between magnetism and warping effects. Finally, we discuss the relevance of our findings to recent experiments about magnetic adatoms and monolayers deposited on TIs.

MA 34.9 Wed 17:15 H32

Towards topological tunnel devices - A versatile method for processing tunnel junctions from high quality single crystals — •Robin Klett[1,2], Karsten Rott[1,2], Daniel Ebke[3], Chandra Shekhar[3], Joachim Schönle[4], Wolfgang Wernsdorfer[4], Stuart Parkin[5], Claudia Felser[1,2], and Günter Reiss[1,2] — [1]Physics Department, Bielefeld University, Germany — [2]Center for Spinelectronic Materials and Devices, Universitätsstraße 25, 33605 Bielefeld, Germany — [3]Max-Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [4]CNRS, Institut NEEL and Univ. Grenoble Alpes, F-38000 Grenoble, France — [5]Max Planck Institute for Microstructure Physics, 06120 Halle/Saale, Germany

We present a new and versatile concept for devices based on topological materials. To maintain their topological character high quality samples with clean interfaces to adjacent functional device components are mandatory. This requirement forms a bottleneck of current research, because very often the established thin film deposition fails to produce such high quality samples and bare surfaces of single crystals lack the necessary flatness. We demonstrate a novel, all-in-ultrahigh-vacuum process that enables to realize, e.g. tunnel junctions, Andreev contacts or SQUID rings from single crystalline bulk material. The validity of the technique is verified and illustrated with tunnel junctions made from cleaved single crystals of the half-Heusler topological superconductor candidate YPtBi.

MA 34.10 Wed 17:30 H32

Effective geometric phases and topological transitions in SO(3) and SU(2) rotations — •Henri Saarikoski[1], J. Enrique Vázquez-Lozano[2], José Pablo Baltanás[2], Junsaku Nitta[3], and Diego Frustaglia[2] — [1]RIKEN Center for Emergent Matter Science, Japan — [2]Departamento de Física Aplicada II, Universidad de Sevilla, Spain — [3]Department of Materials Science, Tohoku University, Japan

We address the development of geometric phases in classical and quantum magnetic moments (spin-1/2) precessing in an external magnetic field. We show that nonadiabatic dynamics lead to a topological phase transition determined by a change in the driving field topology. The transition is associated with an *effective* geometric phase which is identified from the paths of the magnetic moments in a spherical geometry. The topological transition presents close similarities between SO(3) and SU(2) cases but features differences in e.g. the limiting values of the geometric phases [1]. We discuss possible experiments where the effective geometric phase would be observable [2].

[1] H. Saarikoski, J. E. Vázquez-Lozano, J. P. Baltanás, J. Nitta, and D. Frustaglia, arXiv:1511.08315 (2015). [2] H. Saarikoski, J. E. Vázquez-Lozano, J. P. Baltanás, F. Nagasawa, J. Nitta, and D. Frustaglia, Phys. Rev. B 91, 241406(R) (2015).

MA 35: Spin dependent Transport Phenomena

Time: Wednesday 15:00–18:15 Location: H33

MA 35.1 Wed 15:00 H33

Ab initio theory of spin-orbitronics transport effects in disordered Heusler and antiferromagnetic alloys — •Libor Šmejkal[1,2], Karel Carva[2], Ilja Turek[2], and Tomáš Jungwirth[1] — [1]IoP, ASCR, Cukrovarnicka 10/112, CZ-16253 Prague, Czech Republic — [2]DCMP, Charles University, Ke Karlovu 5, CZ-12116 Prague, Czech Republic

We present unified fully relativistic tight-binding linear-muffin-tin-orbital framework for ab initio calculation of spin-orbit torque, anomalous Hall effect, and anisotropic magnetoresistance (AMR) in disordered systems based on coherent potential approximation and Bastin formula.[1-2] We compare our implementation with non-equilibrium Green functions technique, and FLEUR ab initio package.[2-3] Within the developed formalism are calculated aforementioned effects in materials promising for room temperature spin-orbitronics applications (Heusler alloys XMnSb, non-collinear antiferromagnets (AFM) XMn3, and AFM CuMnAs). Finally, the physics gathered from the first-principles calculations is discussed. For instance, the results provide a microscopic theory confirmation of the experimentally measured AMR signals in Ni-rich NiMnSb thin films.[3] AMR has a negative sign and a magnitude reaching 1% for current along the [110] direction, while a strong crystalline term yield an almost perfect cancellation of the AMR for current along the [100] direction.

[1]I. Turek et al., Phys. Rev. B 89 (2014)
[2] F. Freimuth et al., Phys. Rev. B 92 (2015)
[3] C. Ciccarelli et al., eprint arXiv:1510.03356 (2015)

MA 35.2 Wed 15:15 H33

Anomalous magnetothermopower in a metallic frustrated antiferromagnet — •Stevan Arsenijević[1,2,3], Jong Mok Ok[4], Peter Robinson[1,2], Saman Ghannadzadeh[1,2], Mikhail I.

Katsnelson[2], Jun Sung Kim[4], and Nigel E. Hussey[1,2] — [1]High Field Magnet Laboratory (HFML-EMFL), Radboud University, Toernooiveld 7, 6525ED Nijmegen, Netherlands — [2]Radboud University, Institute of Molecules and Materials, Heyendaalseweg 135, 6525, AJ Nijmegen, Netherlands — [3]Dresden High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [4]Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Korea

We report the temperature T and magnetic field H dependence of the thermopower S of an itinerant triangular antiferromagnet $PdCrO_2$ in high magnetic fields up to 32 T. In the paramagnetic phase, the zero-field thermopower is positive with a value typical of good metals with a high carrier density. In marked contrast with typical metals, however, S decreases rapidly with increasing magnetic field, approaching zero at the maximum field scale for $T > 70$ K. We argue here that this profound change in the thermoelectric response is due to the strong interaction of the 4d correlated electrons of the Pd ions with the short-range spin correlations of the Cr^{3+} spins that persist beyond the Néel ordering temperature. Such (chiral) spin correlations are also believed to be responsible for the unconventional anomalous Hall effect that emerges in $PdCrO_2$ at elevated temperatures.

MA 35.3 Wed 15:30 H33

Spin currents injected electrically and thermally from highly spin polarized Co_2MnSi — •Alexander Pfeiffer[1,2], Shaojie Hu[3], Robert M. Reeve[1], Alexander Kronenberg[1], Martin Jourdan[1], Takashi Kimura[3,4], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Mainz, Germany — [3]Research Center for Quantum Nano-Spin Sciences, Kyushu University, Fukuoka, Japan — [4]Department of Physics, Kyushu University, 6-10-1 Hakozaki, Fukuoka 812-8581, Japan

We demonstrate the injection and detection of electrically and thermally generated spin currents in Co_2MnSi/Cu lateral spin valves. Devices with different electrode separations are patterned to measure the non-local signal as a function of the spacing and we determine a high spin polarization of the injected spins of 0.63 and the spin diffusion length in Cu is 500 nm. The electrically generated non-local signal is measured as a function of temperature with a maximum observed for a temperature of 80 K. The thermally generated non-local signal is measured as a function of current density and temperature in a second harmonic measurement detection scheme. We find different temperature dependences for the electrically and thermally generated non-local signals, which allows us to conclude that the temperature dependence of the signals is not just dominated by the transport in the Cu wire, but there is a crucial contribution from the different generation mechanisms, which has been largely disregarded till date. A. Pfeiffer et al., Appl. Phys. Lett. 107, 082401 (2015)

MA 35.4 Wed 15:45 H33

Room temperature operation of n-type Si spin MOSFET — •Masashi Shiraishi[1], Takayuki Tahara[1], Hayato Koike[2], Sasaki Tomoyuki[2], Yuichiro Ando[1], Makoto Kameno[1,3], Kazuyuki Tanaka[3], Shinji Miwa[3], and Yoshishige Suzuki[3] — [1]Kyoto University, Japan — [2]TDK Corporation, Japan — [3]Osaka University, Japan

Si spintronics has been collecting tremendous attention, because of its long spin lifetime and achievement of spin transport at room temperature (RT) [1,2]. In 2014, we have demonstrated the room temperature spin transport in non-degenerate Si [3], and the next milestone was set to be realization of Si spin MOSFET. In this presentation, we report on our experimental demonstration of Si spin MOSFET with high on/off ratio of spin signals. The on/off ratio is greater than 103, whereas on/off ratio in a conventional MOSFET operation is ca. 105. More importantly, the gate voltage dependence of the spin signals and the MOSFET signals are in good agreement [4]. This achievement can pave the way to a practical application of Si spin MOSFETs.

References : [1] T. Suzuki, M. Shiraishi et al., Appl. Phys. Express 4, 023003 (2011). [2] E. Shikoh, M. Shiraishi et al., Phys. Rev. Lett. 110, 127201 (2013). [3] T. Sasaki, M. Shiraishi et al., Phys. Rev. Applied 2, 034005 (2014). [4] T. Tahara, M. Shiraishi, et al., Appl. Phys. Express 8, 113004 (2015) (selected as Spotlight Paper).

MA 35.5 Wed 16:00 H33

***Ab initio* investigations on the magneto-thermoelectric properties of the Co_2TiZ (Z = Si, Ge, Sn) Heusler alloys** — •Voicu Popescu[1], Peter Kratzer[1], Diemo Ködderitzsch[2], and Hubert Ebert[2] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Department Chemie/Physikalische Chemie, Ludwig Maximilian University, 81377 Munich, Germany

The half-metallic ferromagnetic full Heusler alloys Co_2TiZ (Z = Si, Ge, Sn) have been experimentally reported to exhibit a negative Seebeck coefficient with a large absolute value for a metal. Moreover, the temperature dependence of both the resistivity and the Seebeck coefficient display a cusp at the magnetic Curie temperature, a behavior that was so far insufficiently explained by standard band structure approaches.

We investigate, by means of *ab initio* calculations performed within the framework of the full potential spin-polarized relativistic Korringa-Kohn-Rostoker Green function method, to what extent yet unexplored effects are influencing the magneto-transport properties in these systems. We account for electron correlations (GGA+U), substitutional disorder and temperature dependent scattering of the charge carriers by lattice vibrations and spin fluctuations. Among these, we show that only the last two factors are considerably improving the qualitative and quantitative agreement between the calculated and the reported experimental results.

MA 35.6 Wed 16:15 H33

Molecular Anisotropic Magnetoresistance — •Fabian Otte[1], Stefan Heinze[1], and Yuriy Mokrousov[2] — [1]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Using density functional theory calculations, we study ballistic transport in metal-benzene complexes contacted by 3d transition-metal wires. The electronic structure is obtained using the one-dimensional version of the full-potential linearized augmented plane-wave method as implemented in `FLEUR` [1], and is further projected onto the set of maximally-localized Wannier functions. In terms of this localized basis a tight-binding like Hamiltonian is constructed, which is treated in a Green's function formalism to obtain the transmission function [2]. We demonstrate that the anisotropic magnetoresistance (AMR) can be enhanced by orders of magnitude with respect to conventional bulk ferromagnets in junctions containing molecules sandwiched between ferromagnetic leads [3]. We attribute this effect to the orbital-symmetry filtering of the molecules, which drastically enhance the AMR arising from spin-orbit coupling effects in the leads. We further show that such molecular anisotropic magnetoresistance can be tuned by proper choice of materials and their electronic properties.

[1] Y. Mokrousov *et al.*, Phys. Rev. B **72**, 045402 (2005).
[2] B. Hardrat, N.-P. Wang *et al.*, Phys. Rev. B **85**, 245412 (2012).
[3] F. Otte, S. Heinze, and Y. Mokrousov, arXiv:1510.06632.

15 min. break

MA 35.7 Wed 16:45 H33

Disentangling interface and bulk contributions to the anisotropic magnetoresistance in Pt/Co/Pt sandwiches — •André Kobs[1,2] and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany

We present the *pure* Co thickness dependence of the anisotropic magnetoresistance (AMR) in Pt(5nm)/Co(t_{Co})/Pt(3nm) sandwiches at room temperature ($0.8 \le t_{Co} \le 50$ nm) obtained by a detailed analysis of the experimental data that were used to prove the existence of the anisotropic interface magnetoresistance (AIMR) effect [1]. The analysis was triggered by a controversy that came up in a discussion about the properties of AIMR [2,3] and demonstrates that the interfacial AMR is also present when varying the magnetization within the film plane [4]. This interfacial in-plane AMR is two times smaller than the contribution that arises when the magnetization is varied in the plane perpendicular to the current direction. This finding is in contrast to the spin Hall MR found for ferromagnetic insulator/Pt bilayers [5] revealing the existence of different MR effects at the interfaces of Pt with conducting and insulating ferromagnets. Financial support by DFG via OE 251/7-1 and SFB 668 is gratefully acknowledged. [1] A. Kobs and H. P. Oepen *et al.*, PRL **106**, 217207 (2011). [2] A. Kobs, A. Frauen, and H. P. Oepen, PRB **90**, 016401 (2014). [3] S. Y. Huang *et al.*, Phys. Rev. B **90**, 016402 (2014).[4] A. Kobs and H. P. Oepen,

submitted to PRB. [5] H. Nakayama *et al.*, PRL **110**, 206601 (2013).

MA 35.8 Wed 17:00 H33

Giant spin Nernst effect induced by resonant scattering at surfaces of metallic films — •N. H. Long, P. Mavropoulos, B. Zimmermann, S. Blügel, and Y. Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The spin Nernst effect (SNE), where a transverse spin current is generated in a metal by an applied temperature gradient, is expected to open new possibilities in the field of spin caloric transport. However, due to limitations on the magnitude of temperature gradients in metals, the magnitude of SNE observed in experiments is rather small.

In this work, a new concept for engineering a giant SNE in metallic films is proposed by means of resonant impurity scattering. Extending the Fert and Levy model [1] for the spin Hall effect to the case of SNE, we found that scattering off sharp resonant impurity states leads to a strong asymmetric energy-dependence of charge and spin conductivities, as well as of the spin Hall angle. As a result, the spin Nernst conductivity (SNC) is predicted to be gigantic in a wide range of temperatures. By employing the first-principles relativistic full-potential Korringa-Kohn-Rostoker Green function method, we demonstrate that the SNC in Ag(111) films with 1% covarage of Pb or Cr adatom impurities can reach up to 200 (A/K m) at 300 K, exceeding up to one order of magnitude the values of the SNE reported so far.

We acknowledge funding from SPP 1538 SpinCaT programme and HGF-YIG Programme VH-NG-513.

[1] A. Fert and P. M. Levy, Phys. Rev. Lett. **106**, 157208 (2011).

MA 35.9 Wed 17:15 H33

Material analysis of the spin and anomalous Hall efffect in dilute magnetic alloys — •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

The spin Hall effect (SHE) [1] and anomalous Hall effect (AHE) [2] are two allied transport phenomena caused by spin-orbit coupling. For dilute alloys, the dominant contribution to these effects is given by the skew-scattering mechanism. For relatively light hosts with heavy p scatterers, this mechanism causes the so-called giant SHE, as was obtained for Bi impurities in copper [3-5].

Here, we explore the strength of the skew-scattering mechanism in various dilute alloys based on Fe, Co, and Ni crystals by means of *ab initio* calculations performed within a semiclassical approach of Refs. [6,7]. Considering the SHE and the AHE in the investigated systems, an extensive study is presented uncovering trends and underlying microscopic processes.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015); [2] Nagaosa *et al.*, Rev. Mod. Phys. **82**, 1539 (2010); [3] Gradhand *et al.*, Phys. Rev. B **81**, 245109 (2010); [4] Niimi *et al.*, Phys. Rev. Lett. **109**, 156602 (2012); [5] Fedorov *et al.*, Phys. Rev. B **88**, 085116 (2013); [6] Gradhand *et al.*, Phys. Rev. Lett. **104**, 186403 (2010); [7] Zimmermann *et al.*, Phys. Rev. B **90**, 220403(R) (2014).

MA 35.10 Wed 17:30 H33

Longitudinal and transverse transport in Gadolinium at finite temperatures — •Kristina Chadova[1], Sergiy Mankovsky[1], Svitlana Polesya[1], Jan Minar[1,2], Diemo Ködderitzsch[1], and Hubert Ebert[1] — [1]Universität München, Department Chemie, Butenandtstr. 5-13, D-81377 München — [2]New Technologies-Research Centre, University of West Bohemia, Univerzitni 8, 306 14 Pilsen, Czech Republic

Finite temperature effects have a pronounced impact on the transport properties of the solids. In magnetic systems, besides the scattering of conduction electrons by impurities and phonons, an additional scattering source coming from the magnetic degrees of freedom must be taken into account. A first-principle scheme which treats all these scattering effects on equal footing was recently implemented within the framework of the multiple scattering formalism [1]. Employing the alloy analogy model treated by means of the CPA, the thermal lattice vibrations and spin fluctuations are effectively taken into account. The calculation of the transport properties is based on the Kubo-Středa equation. The computational scheme is implemented using the fully relativistic KKR Green function method. As an example, we consider the temperature dependence of the longitudinal resistivity and the anomalous Hall effect in the strongly correlated metal Gd. The comparison with experiments demonstrates that the proposed numerical scheme does, indeed, provide an adequate description of the DC electronic transport coefficients at finite temperatures.

[1] H. Ebert *et al.*, PRB **91**, 165132 (2015).

MA 35.11 Wed 17:45 H33

Interfacial spin-orbit fields in ferromagnet/normal metal (FN) and ferromagnet/superconductor (FS) systems — •Petra Högl[1], Alex Matos-Abiague[2], Igor Zutic[2], and Jaroslav Fabian[1] — [1]University of Regensburg, Germany — [2]University at Buffalo, State University of New York, USA

Breaking of space-inversion symmetry at interfaces induces spin-orbit fields as an emergent phenomenon. Interfacial spin-orbit fields are believed to enable a wealth of new phenomena, not existent or fragile in the bulk, such as the tunneling anisotropic magnetoresistance (TAMR), interfacial spin-orbit torques, Skyrmions, or possible realization of topological superconductors. We theoretically investigate spin-polarized transport in FN and FS junctions in the presence of Rashba and Dresselhaus interfacial spin-orbit fields. The interplay of magnetism and spin-orbit fields leads to a marked magnetoanisotropy of the conductances. Remarkably, the anisotropy in FS systems–magnetoanisotropic Andreev reflection (MAAR)–is giant compared to TAMR, its normal-state counterpart in FN junctions [1]. We further report on the dependence of spin-flip probability currents on characteristic system parameters [2]. This work has been supported by DFG SFB 689, Int. Doct. Prog. Top. Insulators of Elite Network of Bavaria, DOE-BES Grant No. DE-SC0004890, and ONR N000141310754.

[1] P. Högl, A. Matos-Abiague, I. Žutić, J. Fabian, Phys. Rev. Lett. **115**, 116601 (2015)

[2] A. M. Kamerbeek, P. Högl, J. Fabian, T. Banerjee, Phys. Rev. Lett. **115**, 136601 (2015)

MA 35.12 Wed 18:00 H33

Investigation of ac currents and spin excitations triggered by dynamical Hall effects — •Filipe Souza Mendes Guimarães[1], Manuel dos Santos Dias[1], Antonio Tavares da Costa Jr[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

Hall effects involving the interchange of charge, spin and orbital angular momentum may be used to excite and measure properties of nanostructures. Present theoretical descriptions of these effects ignore the dynamical character of the transport and excitation processes. We demonstrate, in a fully quantum mechanical and dynamical approach, how ferromagnetic and antiferromagnetic resonances can be excited by dynamical spin accumulations induced by the ac spin Hall effect in Fe/W bilayers and Fe/W/Fe trilayers. [1] Moreover, focusing on Co/Pt bilayers, we explore how intrinsic dynamical anomalous Hall effect, planar Hall effect and anisotropic magnetoresistance can be seen in a unified picture.

We acknowledge funding from CAPES (Brazil), Alexander von Humboldt foundation (Germany) and HGF-YIG Programme VH-NG-717 (Funsilab).

[1] F. S. M. Guimarães, S. Lounis, A. T. Costa, and R. B. Muniz, accepted in PRB: Rapid Communications, (2015). [arXiv:1509.04599]

MA 36: Magnetization and Demagnetization Dynamics III

Time: Wednesday 15:00–18:15 Location: H34

MA 36.1 Wed 15:00 H34

Influence of magneto-elastic coupling in magnetization dynamics — •Matthias Assmann and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

For modern nanoscale devices a profound understanding of the atomistic interactions is crucial. Modern experiments have access to magnetization dynamics on femtosecond timescale as well as to phononic excitations. We developed therefore a model, which allows a coupling between these two thermodynamic sub-systems under strict observance of energy and angular momentum conservation laws. For this model we perform spin-molecular dynamics simulations, which take into account the spatial as well as the spin degrees of freedom. This coupling between the spin and lattice degrees of freedom is achieved by pseudo dipolar forces. These coupling contributes to various effects like damping, domain wall movement and magneto-volume effects.

MA 36.2 Wed 15:15 H34

Magnetization dynamics driven by surface acoustic waves — Eric R. J. Edwards, •Rouven A. Dreyer, Niklas Liebing, and Georg Woltersdorf — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Deutschland

We use surface acoustic waves (SAW) to excite magnetization dynamics magneto-elastically in magnetic film and elements. Here we present a detailed experimental analysis of SAW driven ferromagnetic resonance in Nickel elements with different sizes as function of the external magnetic field amplitude, magnetic field orientation and SAW frequency (and wave vector). In the experiments the surface acoustic waves are excited at the surface of LiNbO3 substrates using lithographically patterned interdigital transducers (IDT). At the same time the induced magnetization dynamic is probed locally by time-resolved Kerr microscopy. The frequency (and wave vector) dependence of the SAW driven FMR is measured, using odd harmonics of the IDT fundamental frequency. The experimental results are described by a model based on the magneto-elastic coupling.

MA 36.3 Wed 15:30 H34

Relevance of the exchange coupling in ultrafast demagnetization of ferromagnetic alloys — •Stefan Günther[1,12], Carlo Spezzani[2,11], Roberta Ciprian[3], Cesare Grazioli[2,4], Barbara Ressel[4], Marcello Coreno[2,5], Luca Poletto[6], Paolo Miotti[6], Maurizio Sacchi[7,8,9], Giancarlo Panaccione[3], Vojtěch Uhlíř[10], Eric E. Fullerton[10], Giovanni De Ninno[2,4], Christian H. Back[1], and Manfred Fiebig[12] — [1]University of Regensburg — [2]Elettra Sincrotrone Trieste — [3]IOM-CNR, Triest — [4]University of Nova Gorica — [5]CNR-IMIP, Rome — [6]CNR-IFN, Padova — [7]Sorbonne Universités, Paris — [8]Centre national de la recherche scientifique, Paris — [9]Synchrotron SOLEIL, Saint-Aubin — [10]University of California, San Diego — [11]University Paris Sud — [12]ETH Zürich

We use element-resolved infrared-pump/extreme ultraviolet-probe experiments to disentangle the ultrafast interplay of magnetic alloys during ultrafast demagnetization. As paradigmatic examples, we investigate the cases of the FeRh alloy (crystalline and ordered), FeCo alloy (crystalline but disordered) and FeNi alloy (polycrystalline). All three systems reveal different dynamics for the alloy's components and a distinct time difference in the onset of the demagnetization is observed. The magnitude of this temporal delay is related to the interatomic exchange interaction for all three systems where the mismatch of the demagnetization traces decreases with stronger coupling.

MA 36.4 Wed 15:45 H34

Ultrafast magnetization dynamics in amorphous FeGd alloys — •Raghuveer Chimata — Department of Physics and Astronomy, Uppsala University, Box-516 Uppsala

In recent years, there has been an intense interest in understanding the microscopic mechanism of thermally induced magnetization switching driven by a femtosecond(fs) laser pulse. Most of the efforts have been dedicated to periodic crystalline structures while the amorphous counterparts have been less studied. By using a multiscale approach, i.e. first-principles density functional theory combined with atomistic spin dynamics, we report here on the very intricate structural and magnetic nature of amorphous Gd-Fe alloys for a wide range of Gd and Fe atomic concentrations at the nanoscale level. Both structural and dynamical properties of Gd-Fe alloys reported in this work are in good agreement with previous experiments. We calculated the dynamic behavior of homogeneous and inhomogeneous amorphous Gd-Fe alloys and their response under the influence of a fs laser pulse. In the homogeneous sample, the Fe sublattice switches its magnetization before the Gd one. However the switching process is reversed in the inhomogeneous sample. Furthermore, our results point out that a microscopic mechanism for all-thermal switching does not need to involve spin current effects.

MA 36.5 Wed 16:00 H34

Ultrafast and energy-efficient spin manipulation: Antiferromagnetism beats Ferromagnetism — •Nele Thielemann-Kühn[1,2], Daniel Schick[1], Niko Pontius[1], Christoph Trabant[1,2,3], Rolf Mitzner[1], Karsten Holldack[1], Hartmut Zabel[4], Alexander Föhlisch[1,2], and Christian Schüssler-Langeheine[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Germany — [3]II. Physikalisches Institut, Universität zu Köln, Germany — [4]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

The wealth of studies in the field of ultrafast magnetic dynamics brought the understanding that the speed limit for spin manipulation comes from the achievable angular momentum transfer rate. In ferromagnets with net magnetization, any change of magnetic order requires transfer of angular momentum out of the spin system. Magnetic materials with non-parallel spins like antiferromagnets, offer the possibility to manipulate magnetic order by redistributing angular momentum within the spin system itself. We compare ferro (FM) - and antiferromagnetic (AFM) dynamics in one and the same material - metallic Dy - and find indeed clear differences. AFM spin order is faster manipulated by optical excitation than its FM counterpart. We assign the fast process in the AFM phase to an interatomic transfer of angular momentum within the spin system. Our findings point out a possible route towards ultrafast spin manipulation for magnetic devices.

MA 36.6 Wed 16:15 H34

Ultrafast magnetization dynamics FeRh — •Robert Carley[1], Manuel Izquierdo[1], Sebastian Carron[6], Tyler Chase[4], Bruce Clemens[4], Georgi Dakovski[6], Eric Fullerton[5], Patrick Granitzka[4], Alexander Gray[3], Stefan Günther[2], Daniel Higley[4], Emmanuelle Jal[3], Loïc Le Guyader[7], Joel Li[4], Serguei Molodtsov[1], Mike Minitti[6], Ankush Mitra[6], Alexander Reid[3], William Schlotter[6], Vojtech Uhlir[5], Joachim Stöhr[3], Hermann Dürr[3], Christian Back[2], Andreas Scherz[1], Alexander Yaroslavtsev[1], and Ruslan Kurta[1] — [1]European XFEL, Germany — [2]Universität Regensburg, Germany — [3]Stanford Institute for Materials and Energy Science, USA — [4]Stanford University, USA — [5]University of California San Diego, USA — [6]Linac Coherent Light Source, Stanford, USA — [7]Helmholtz Zentrum Berlin für Materialien und Energie, Germany

We report on an experimental study of the laser-driven antiferromagnetic (AFM) to ferromagnetic (FM) phase transition in FeRh using the time-, element-, and spatially resolving technique of resonant x-ray diffraction at the Fe L3 edge. We observe sub-ps magnetic transients followed by FM nucleation on the 10 ps timescale, and finally slower domain dynamics. This contribution will focus on the sub-ps dynamics, which provide a detailed insight into the microscopic mechanisms underlying the AFM-FM transition.

15 min. break

MA 36.7 Wed 16:45 H34

Temperature dependent laser induced magnetization switching in $Tb_{22}Fe_{69}Co_9$ ferrimagnetic thin film by photoelectron emission microscopy — •Ashima Arora, Lukas Gierster, Ahmet Ünal, and Florian Kronast — Helmholtz-Zentrum Berlin, Albert-Einstein Str. 15, 12489 Berlin, Germany

All optical helicity dependent switching has drawn a significant attention for data storage applications in the view of controlling the magnetic state of material without applying high magnetic fields. It has been shown in the previous studies that the magnetization of ferrimagnets like $Tb_{22}Fe_{69}Co_9$ can be altered by circularly polarized femtosecond laser pulses[1-2]. This magnetization reversal process involves a competition between different effects arising from laser heating, helicity dependent momentum transfer and dipolar fields. Using X-Ray photoelectron emission microscopy (PEEM), we distinguished the influence of the three effects using a μm sized laser spot [3]. To investigate the magnetic switching in greater detail, measurements were performed at different temperatures which show that the effect of helicity dependent switching is stronger at lower temperatures. We observe that the total area switched by a single circularly polarized femtosecond laser pulse and the average domain size, both increase with the sample temperature. These observations might be attributed to temperature dependent threshold in laser switching process.

1. S.Mangin et al., Nat. Mater. 13, 286-292 (2014)
2. C-H. Lambert et al., Science 345, 6202(2015)
3. L. Gierster et al., Ultramicroscopy (2015) doi:10.1016/j.ultramic.2015.05.016

MA 36.8 Wed 17:00 H34

Brillouin Light Scattering study of magnon-photon strong coupling in a split-ring resonator / YIG film system — •Stefan Klingler[1,2], Hannes Maier-Flaig[1,2], Rudolf Gross[1,2,3], Can-Ming Hu[4], Hans Hübl[1,2,3], Sebastian T. B. Goennenwein[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 Initiative Munich, Munich, Germany — [4]Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada

In coupled microwave resonator/magnetic hybrid systems an anticrossing of photonic and magnonic dispersions can occur.

Here, we use microfocused Brillouin Light Scattering (BLS) to study this magnon-photon coupling phenomenon. The BLS detection affords us with frequency-resolved detection of magnonic excitations. We employ a lithographically defined split-ring resonator (SRR) loaded with a 3 μm-thick Yttrium Iron Garnet (YIG) film grown by liquid phase epitaxy. We simultaneously record BLS spectra and the microwave transmission (MT) of the hybrid system as a function of external magnetic field magnitude and microwave excitation frequency. From this data, we find strong coupling of the magnonic and photonic modes with a coupling strength of ≈60 MHz at an excitation frequency of ≈5 GHz. Light-polarization dependent measurements confirm that BLS and MT spectroscopy are sensitive to the magnonic and photonic parts of the coupled magnon-photon mode, respectively.

MA 36.9 Wed 17:15 H34

Anomalously low magnetic damping of a metallic ferromagnet $Fe_{1-x}Co_x$ — Martin Schoen[1,2], •Danny Thonig[3], Michael Schneider[1], Thomas Silva[1], Hans Nembach[1], Olle Eriksson[3], Olof Karis[3], and Justin Shaw[1] — [1]Quantum Electromagnetics Division, National Institute of Standards and Technology, USA — [2]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [3]Department of Physics and Astronomy, University Uppsala, Sweden

Scaling of magnetic memory devices will require extremely low Gilbert damping. Ultra low damping (< 0.001), has only been found in nonmetallic materials such as YIG or Heusler alloys. Recent theoretical work by Mankovsky et al. [1], however, predict damping of about 0.0007 in metallic CoFe alloys at 10% Co concentration. Such low values of the damping are highly uncommon in conducting ferromagnetic systems.

To confirm the predictions, we preformed a systematic FMR studies of the damping in Co_xFe_{1-x} systems spanning the full alloy composition range. Our measurements are corroborated by first principle DFT calculations of the electron structure.

We found a minimum of the damping in FeCo at 25% Co concentration, consistent with density of states calculations at 25% Co. The minimum of the damping in $Co_{0.25}Fe_{0.75}$ exhibits a — for conducting ferromagnets unprecedented — low value of $\alpha = 0.0005$, showing the practicality of metal alloys for spintronics.

[1] Mankovsky et al., Phys. Rev. B 87, 014430 (2013)

MA 36.10 Wed 17:30 H34

Nonlinear spin-wave excitations at low magnetic bias fields — Hans G. Bauer[1], Peter Majchrak[1], Torsten Kachel[3], Christian H. Back[1], and •Georg Woltersdorf[1,2] — [1]Department of Physics, University of Regensburg, Universitätsstrasse 31, 93040 Regensburg, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [3]Institut for Methods and Instrumentation in Synchrotron Radiation Research, Helmholtz-Center Berlin for Materials und Energy, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We investigate experimentally and theoretically the nonlinear magnetization dynamics in magnetic films at low magnetic bias fields. In the experiments we use X-ray magnetic circular dichroism to determine the number density of excited magnons in magnetically soft NiFe thin films. Our data show that the common Suhl instability model of nonlinear ferromagnetic resonance is not adequate for the description of the nonlinear behavior in the low magnetic field limit. Here we derive a model of parametric spin-wave excitation, which correctly predicts nonlinear threshold amplitudes and decay rates at high and at low magnetic bias fields. In fact, a series of critical spin-wave modes with fast oscillations of the amplitude and phase is found, generalizing the theory of parametric spin-wave excitation to large modulation amplitudes. Our results also show that it is not required to invoke a wave vector-dependent damping parameter in the interpretation of nonlinear magnetic resonance experiments performed at low bias fields.

MA 36.11 Wed 17:45 H34

Rayleigh-Jeans condensation of pumped magnons in thin film ferromagnets — •Andreas Rückriegel and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt

We show that the formation of a magnon condensate in thin ferromagnetic films can be explained within the framework of a classical stochastic non-Markovian Landau-Lifshitz-Gilbert equation where the properties of the random magnetic field and the dissipation are determined by the underlying phonon dynamics. We have numerically solved this equation for a tangentially magnetized yttrium-iron garnet film in the presence of a parallel parametric pumping field. We obtain a complete description of all stages of the nonequilibrium time evolution of the magnon gas which is in excellent agreement with experiments. Our calculation proves that the experimentally observed condensation of magnons in yttrium-iron garnet at room temperature is a purely classical phenomenon which should be called Rayleigh-Jeans rather than Bose-Einstein condensation.

MA 36.12 Wed 18:00 H34

Relativistic theory of spin relaxation mechanisms in the Landau-Lifshitz equations of spin dynamics — •Ritwik Mondal, Marco Berritta, Pablo Maldonado, Alexandros Aperis, and Peter M. Oppeneer — Uppsala University, Uppsala, Sweden

Magnetization dynamics has been successfully applied to spin systems with phenomenological Landau-Lifshitz equations of motion [1]. Here, starting from the Dirac-Kohn-Sham equation we derive the relativistic equation of motion of angular momentum in a magnetic solid taking into account the spin-orbit coupling. This equation of motion can be rewritten in the form of the well-known Landau-Lifshitz equation plus additional relativistic terms which describe the various electronic spin relaxation mechanisms. Thus we derive a damping parameter of Gilbert type [2] (see also [3]). Further, we discuss the dynamics of the total angular momentum within the relativistic Dirac framework including exchange interactions of Heisenberg type.

[1]L.D. Landau and E.M. Lifshitz, Phys. Z. Sowjetunion **8**, 101 (1935). [2]T.L. Gilbert, IEEE Trans. Magn. **40**, 3443 (2004). [3]M.C. Hickey and J.S. Moodera, Phys. Rev. Lett. **102**, 137601 (2009).

MA 37: Transport: Molecular Electronics and Photonics 1 (Joint session of CPP, DS, HL, MA, O and TT organized by TT)

Time: Thursday 9:30–13:00 Location: H23

MA 37.1 Thu 9:30 H23

Pulling and Stretching a Molecular Wire to Tune its Conductance — •Gaël Reecht[1,4], Hervé Bulou[1], Fabrice Scheurer[1], Virginie Speisser[1], Fabrice Mathevet[2], César González[3], Yannick J. Dappe[3], and Guillaume Schull[1] — [1]IPCMS, Strasbourg, France — [2]Laboratoire de Chimie des Polymères, Paris, France — [3]CEA IRAMIS, Saclay, France — [4]Freie Universität Berlin, Berlin, Germany

Molecular junctions are perceived as the ultimate step toward the miniaturization of electronic components based on organic materials. Here, a low temperature scanning tunnelling microscope is used to lift a polythiophene wire from a Au(111) surface while measuring the current traversing the molecular junction. Conductance traces recorded during the lifting procedures reveal abrupt increases of the current intensity, which we associate to detachments of the wire subunits from the surface, in apparent contradiction with the expected exponential decrease of the conductance with wire length. With, ab initio simulations we reproduce the experimental data and demonstrate that this unexpected behavior is due to release of mechanical stress in the wire. Therefore, with the high control ability of the STM, by stretching the suspended molecular wire, we are able to tune its conductance properties.

MA 37.2 Thu 9:45 H23

STM-induced luminescence of single molecule junction — •Michael Chong[1], Gael Reecht[1], Hervé Bulou[1], Alex Boeglin[1], Fabrice Mathevet[2], Fabrice Scheurer[1], and Guillaume Schull[1] — [1]Institut de Physique et Chimie des Matériaux de Strasbourg - CNRS - France — [2]Laboratoire de Chimie des Polymères - CNRS - Université Pierre et Marie Curie, Paris, France

Electroluminescence of a single molecule can be induced by means of scanning tunneling microscopy. When a molecule is placed between two metallic electrodes it is necessary to decouple it using thin insulating layers in order to measure its intrinsic luminescence. A direct contact with the electrodes (tip and substrate), necessary if we envision to build single molecule electronic devices, results in quenching or broadening of the fluorescence of the molecule. We use on-surface polymerization to embed a cromphore molecule in a molecular chain. The STM tip is then used to lift the chain in order to decouple the cromophore from the surface yet mantaining a circuit like configuration trough the molecular chain. The current generated by applying a bias to the electrodes excites the cromophore that then exhibits narrow line luminescence and vibronic peaks allowing chemical identification the emitting unit.

Moreover we demonstrate that this configuration allows to control the lifetime of the excited state of the emitting molecule by two orders of magnitude by changing the coupling of the single molecle with the substrate adjusting the tip-sample separation. This system might open the way to electro-plasmonic devices at the single molecule level.

MA 37.3 Thu 10:00 H23

Effects of spin-orbit coupling and many-body correlations in STM transport through copper phthalocyanine — Benjamin Siegert, •Andrea Donarini, and Milena Grifoni — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

The interplay of exchange correlations and spin-orbit interaction (SOI) on the many-body spectrum of a copper phtalocyanine (CuPc) molecule and their signatures in transport are investigated. We first derive a minimal model Hamiltonian in a basis of frontier orbitals which is able to reproduce experimentally observed singlet-triplet splittings; in a second step SOI effects are included perturbatively. Major consequences of the SOI are the splitting of former degenerate levels and a sizable magnetic anisotropy, which can be captured by an effective low-energy spin Hamiltonian. We show that STM-based magnetoconductance measurements can yield clear signatures of both these SOI induced effects.

MA 37.4 Thu 10:15 H23

Conductance trend in linear oligoacenes controlled by quantum size-effects — •Richard Korytar[1], Tamar Yelin[2], Nirit Sukenik[2], Ran Vardimon[2], Bharat Kumar[3], Colin Nuckolls[3], Oren Tal[2], and Ferdinand Evers[1] — [1]Institute of Theoretical Physics, University of Regensburg, Germany — [2]Chemical Physics Department, Weizmann Institute of Science, Rehovot, Israel — [3]Department of Chemistry, Columbia University, New York, United States

In conventional electronics, the conductance of a wire decreases with length according to Ohm's law. In molecular electronics, quantum effects lead to a richer phenomenology. Oligoacenes are organic molecules which consist of (linearly) fused benzene rings. Recently, Yelin et al. [submitted] studied conductance of oligoacenes directly coupled to Ag leads and found increase of conductance with molecular length.

I will show that transport through oligoacenes is governed by a quantum size effect which controls the alignment and width of the lowest unoccupied molecular orbital. These ideas will be supported by first-principles transport calculations using density-functional theory.

Linear oligoacenes are one of the simplest realizations of zig-zag terminated graphene nano-ribbons. In the long-wire limit, I will demonstrate that the conductance as a function of the molecular length shows surprising oscillations with period of approx. 11 rings [1].

[1] R. Korytár, D. Xenioti, P. Schmitteckert, M. Alouani, and F. Evers, Nature Communications **5**, 5000 (2014).

MA 37.5 Thu 10:30 H23

Investigation of charge transfer processes in single crystals based on π-conjugated molecules — •Antonia Morherr[1], Alisa Chernenkaya[2], Sebastian Witt[1], Katerina Medjanik[3], Michael Bolte[1], Martin Baumgarten[4], Harald O. Jeschke[1], Roser Valentí[1], and Cornelius Krellner[1] — [1]Goethe-Universität Frankfurt, 60438 Frankfurt a. M., Germany — [2]Johannes Gutenberg-Universität, 55099 Mainz, Germany — [3]Lund University, MAX-lab, 22100 Lund, Sweden — [4]MPI für Polymerforschung, 55021 Mainz, Germany

Designing new charge transfer (CT) materials for tuning the physical properties ranging from metallicity over superconductivity to Mott insulators and the understanding of mechanisms of CT is of great interest [1]. New CT crystals of π-conjugated molecules as donors can be obtained by physical vapor transport (PVT) [2]. (Fluorinated) tetracyanoquinodimethane (TCNQ-F_x, x=0, 2, 4) was used as acceptor material to grow different CT salts. The crystal structure was detected by X-ray diffraction. Further spectroscopic measurements as infrared and NEXAFS measurements were applied on these single crystals to investigate the CT process. The analysis of N1s and F1s K-edge spectra shows changes for different acceptor strengths. Ab initio calculations for all compounds underline these results. This systematic investigation of CT materials helps to understand the CT process in more detail.

[1] N. Toyota, M. Lang, J. Müller, Low-Dimensional Molecular Metals, Springer-Verlag, Berlin, 2007
[2] B. Mahns et al., Cryst. Growth Des. **14**, 1338 (2014)

MA 37.6 Thu 10:45 H23

Single Molecule Junctions with Epitaxial Monolayer Graphene Electrodes — •Konrad Ullmann[1], Pedro B. Coto[2], Susanne Leitherer[2], Michael Thoss[2], and Heiko B. Weber[1] — [1]Lehrstuhl für Angewandte Physik und Interdisziplinäres Zentrum für Molekulare Materialien, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) — [2]Institut für Theoretische Physik und Interdisziplinäres Zentrum für Molekulare Materialien, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

To study transport through single molecules, a two dimensional, open-access testbed for individual molecules is desirable. Therefore we use epitaxial monolayer graphene to fabricate electrodes for single molecule junctions. With the help of a feedback-controlled electro-burning process nanometer sized gaps can be formed reproducibly. Using these electrodes, we studied transport through molecules with different anchor groups at low temperatures. Strong similarities in results obtained with the MCBJ-technique underline the high quality of our experimental data. For a fullerene-endcapped molecule we are able to assign features from the I-V characteristics to internal molecular degrees of freedom [1].

[1] K. Ullmann et al., Nano Lett. **15**, 3512 (2015)

MA 37.7 Thu 11:00 H23

Simulation of Electron Transport through Graphene-Molecule Junctions — •Susanne Leitherer[1], Uwe Frank[1], Konrad Ullmann[2], Pedro B. Coto[1], Heiko Weber[2], and Michael Thoss[1] — [1]Institute for Theoretical Physics and Interdisciplinary Center for Molecular Materials, University Erlangen-Nürnberg — [2]Chair of Applied Physics and Interdisciplinary Center for Molecular Materials, University Erlangen-Nürnberg

Charge transport in single-molecule junctions with graphene electrodes is investigated using a combination of density functional theory (DFT) electronic structure calculations and Landauer transport theory. In particular, we study covalently bonded molecule-graphene junctions as well as junctions, where the molecule is weakly bonded to graphene by van der Waals interaction [1]. Considering different examples for molecular bridges between graphene electrodes, we analyze the transmission probability and current-voltage characteristics. In junctions with zigzag terminated graphene electrodes, we find edge states, which can induce additional transport channels [2]. Furthermore, local conductance properties are investigated in the nanojunctions.

[1] K. Ullmann et al., Nano Lett. **15**, 3512 (2015)

[2] I. Pshenichnyuk et al., J. Phys. Chem. Lett. **5**, 809 (2013)

15 min. break

MA 37.8 Thu 11:30 H23

Electron transport through C_{20} molecular junction — •Shigeru Tsukamoto and Stefan Blügel — PGI-1/IAS-1, Forschungszentrum Jülich and JARA, Jülich, Germany

We present electron transport properties of C_{20} molecular junctions, which are evaluated within the framework of the density functional theory. The C_{20} molecular junctions employed in this work are composed of a pair of Al bulk electrodes and a single C_{20} molecule, which is known as the smallest fullerene molecule. The scattering wave functions of the molecular junctions are calculated by solving the Kohn-Sham equation by means of the over-bridging boundary matching method, which is based on the real-space finite-difference formalism. The transmission properties are extracted from the scattering wave functions and the electron transmissions are evaluated by the Landauer-Büttiker formula. The electron transmissions and the scattering wave functions are further analyzed by using the eigenchannel decomposition technique. As the result of the eigenchannel analysis, although the total transmission value is $\sim 3.0G_0$ at around the Fermi level, more than five transmission channels are found to contribute to the electron transport, and none of the eigenchannels are opened to 100%. From the spatial distributions of the eigenchannels, we can see that the HOMO states of C_{20} molecule, which are three-fold degenerated and occupied to one-third, mainly contribute to the transport. In addition, the LUMO state is also found to contribute as one of the eigenchannels at around the Fermi level. In the talk, we will present electron transport calculations with different molecular orientations.

MA 37.9 Thu 11:45 H23

Quantum interference effect transistor via "Kondo Blockade" in single molecule junctions — •Andrew Mitchell[1] and Jens Paaske[2] — [1]Institute for Theoretical Physics, Utrecht University, 3584 CE Utrecht, The Netherlands — [2]Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark

Single molecule junctions are basic building blocks of molecular electronics devices. The full power of these devices will be realized by exploiting inherent quantum mechanical effects. Two of the most striking quantum phenomena, with no classical analogue, are quantum interference (QI) due to competing electron transport pathways, and the Kondo effect (KE) due to entanglement and strong electronic interactions. Both QI and KE are widely observed in experiments. The description of QI accounts for the complexities of molecular structure, but is typically non-interacting. By contrast, the Anderson impurity model is usually used to describe interactions and the Kondo effect, but totally neglects molecular structure. In this talk I discuss the subtle interplay between QI and KE in a unified theory, showing that a novel gate-tunable "Kondo Blockade" regime can be exploited to realize an efficient quantum interference effect transistor.

MA 37.10 Thu 12:00 H23

Quantitative *ab initio* simulations of nanocarbon-metal extended contacts — •Artem Fediai[1,2], Dmitry Ryndyk[1,2], and Gianaurelio Cuniberti[1,2,3] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, TU Dresden — [2]Center for Advancing Electronics Dresden, TU Dresden — [3]Dresden Center for Computational Materials Science, TU Dresden, 01062 Dresden, Germany

Recently developed approach presented in [1] allows to get quantitative information about the resistance R_c, effective contact length L_c, and contacts resistance scaling $R_c(L_c)$ in different extended side contacts depending on the electrode material. We apply this approach to find a contact resistance of side CNT-metal contacts, transfer length in graphene-metal contacts and electronic properties of the diodes with CNT channel and asymmetric contacts (with the electrodes made of different metals). These kinds of *ab initio* simulations were previously impossible due to numerical intractability of the side contacts longer then several nanometers. Our approach explicitly uses extended contact model concept, enforced by modular approach. This allows us to overcome numerical problems and understand physical processes in extended contacts.

[1] A. Fediai, D.A. Ryndyk, G. Cuniberti, PRB **91**, 165404 (2015)

MA 37.11 Thu 12:15 H23

Molecular switches for dangling bond circuits — •Thomas Lehmann[1,2], Dmitry A. Ryndyk[1,2], and Gianaurelio Cuniberti[1,2] — [1]Institute for Materials Science and Max Bergmann Center of Biomaterials, TU Dresden, Germany — [2]Dresden Center for Computational Materials Science (DCMS), TU Dresden, Germany

On the road to atomic-scale electronic circuits, dangling bond wires are promising candidates. Dangling bonds are formed by selectively removing hydrogen from a passivated silicon surface [1,2] and multiple dangling bonds in a row feature extended electronic states. Those quasi 1D surface structures can be used as atomic scale interconnects. In such circuits, molecules, which can controllably passivate or depassivate a dangling bond can provide logical inputs for constructing simple logic elements. In this talk, we present recent studies combining density-functional based approaches with Green function methods of a molecular switch for dangling bond wires on silicon.

[1] T. Hitosugi, T. Hashizume, S. Heike, S. Watanabe, Y.Wada, T. Hasegawa, K. Kitazawa, Jpn. J. Appl. Phys. **36**, L361 (1997)

[2] H. Kawai, F. Ample, Q. Wang, Y. K. Yeo, M. Saeys, C. Joachim, J. Phys. Condens. Matter **24**, 095011 (2012)

MA 37.12 Thu 12:30 H23

Switchable negative differential resistance induced by quantum interference effects in porphyrin-based molecular junctions — •Daijiro Nozaki[1], Lokamani Lokamani[2], Alejandro Santana-Bonilla[2], Arezoo Dianat[2], Rafael Gutierrez[2], Gianaurelio Cuniberti[2], and Wolf Gero Schmidt[1] — [1]Lehrstuhl für Theoretische Physik, Universität Paderborn, Paderborn, Germany — [2]Institute for Materials Science, TU Dresden, Dresden, Germany

Charge transport through a carbon-based molecular switch consisting of different tautomers of metal-free porphyrin embedded between graphene nanoribbons is studied by combining electronic structure calculations and nonequilibrium Green's function formalism. Different low-energy and low-bias features are revealed, including negative differential resistance (NDR) and antiresonances, both mediated by subtle quantum interference effects. Moreover, the molecular junctions can display moderate rectifying or nonlinear behavior depending on the position of the hydrogen atoms within the porphyrin core. We rationalize the mechanism leading to NDR and antiresonances by providing a detailed analysis of transmission pathways and frontier molecular orbital distribution.

[1] D. Nozaki, J. Phys. Chem. Lett. **6**, 3950 (2015).

MA 37.13 Thu 12:45 H23

Base alignment dependence on Seebeck coefficient of DNA: A diagrammatic non-equilibrium transport theory approach — •Yoshihiro Asai[1], Yueqi Li[2], Limin Xiang[2], Julio L. Palma[2], and Nongjian Tao[2] — [1]Research Center for Computational Design of Advanced Functional Materials, AIST, Central 2, Umezono 1-1-1, Tsukuba, Ibaraki 305-8568, Japan — [2]Center for Bioelectronics and Biosensors, Biodesign Institute, Arizona State University, Tempe, Arizona 85287-5801, USA

Theoretical calculation of temperature dependence of transport properties at finite bias voltage and/or at finite temperature gradient requires careful description of low energy excitations. Incorporation of phonon transport and its coupling to electron transport by no means should play a crucial role to describe the low energy physics. One of the authors succeeded to describe theoretically the temperature cross over behavior of the electric conductance found in the experiment of a long oligothiophene single molecular wires. The diagrammatic non-equilibrium transport theory is useful to describe the problem qualitatively. While the necessity of the non-perturbative approach to the problem is clear, it would be interesting to know how far we could go within the perturbative framework given that any reliable non-perturbative approach for the problem is not available at present. Here, we apply the theory to discuss the base alignment dependence of the Seebeck coefficient of DNA in the hopping temperature region. We will make comparative discussions on our theoretical results with our experimental ones.

MA 38: Multiferroics I (DF with MA)

Time: Thursday 9:30–12:50 Location: H25

MA 38.1 Thu 9:30 H25

Room-temperature electric-field-induced magnetic anisotropy rotation in multiferroic heterostructures — •Gabriele De Luca, Peggy Schönherr, Manfred Fiebig, and Morgan Trassin — ETH Zürich, Department of Materials

The possibility to control magnetic anisotropy by using only an electric field has rendered compounds with interacting ferromagnetic and ferroelectric order a prime target of materials research. However, both orders hardly coexist at room-temperature in a single material phase, thus efforts focused on artificial heterostructures and magnetoelectric coupling as a composite effect. Here we design a multiferroic heterostructure Pt/CoFe/BiFeO3 (BFO) and we use a combination of magnetic force microscopy (MFM) and second harmonic generation (SHG) to detect the distribution of the ferromagnetic domains in CoFe and the buried ferroelectric domain state in BFO. With SHG we establish a unique relation between the BFO domains distribution and the nonlinear response and we perform the read-out without invading the system [1]. MFM reveals the one-to-one coupling of the ferroelectric/ferromagnetic domains. With an external electric field, we induce changes in the BFO ferroelectric state and we use magnetic field dependent MFM to probe the resulting effect on the CoFe domains and magnetic anisotropy. Previous work has unveiled in such systems that the net CoFe magnetization can be electrically reversed. Here we show that local magnetic anisotropy rotation can be achieved and correlated with the underlying ferroelectric domain state after voltage application. [1] M. Trassin, G. De Luca et al., Adv. Mater. 27, 4871 (2015)

MA 38.2 Thu 9:50 H25

Design and synthesis of a room temperature multiferroic bulk oxide — Pranab Mandal[1], •Michael Pitcher[1], Jonathan Alaria[2], Hongjun Niu[1], Pavel Borisov[1], Plamen Stamenov[3], John Claridge[1], and Matthew Rosseinsky[1] — [1]Department of Chemistry, University of Liverpool, Liverpool, UK — [2]Department of Physics, University of Liverpool, Liverpool, UK — [3]CRANN, Trinity College Dublin, Ireland

A new generation of low-power high-density information storage would be enabled by the development of multiferroic materials that combine switchable electrical polarisation (conventionally arising from second order Jahn-Teller distortion of d^0 cations) with spontaneous magnetisation (from long range ordering of unpaired d electrons) within a single phase material. Combining these properties at room temperature is very challenging due to their antagonistic electronic requirements and the need to maintain long range magnetic ordering to such high temperatures. We have demonstrated a new route to such materials, first by engineering competitive ferroelectric performance in a Bi-based perovskite by creating a PZT-like morphotropic phase boundary in the solid solution [1-x] $BiFe_{2/8}Mg_{3/8}Ti_{3/8}O_3$ - [x]$CaTiO_3$ ($0 < x < 0.40$); and then introducing long range magnetic order to this ferroelectric platform by increasing the concentration of Fe^{3+} above the threshold required for a percolating superexchange network. The resulting materials are magnetoelectric, ferromagnetic and ferroelectric above 300 K.

MA 38.3 Thu 10:10 H25

Multiferroic clusters: a new perspective for relaxor-type room-temperature multiferroics — •Leonard Henrichs[1,2], Oscar Cespedes[3], Wolfgang Kleemann[4], and Andrew Bell[2] — [1]Karlsruher Institut für Technologie, Institut für Angewandte Geowissenschaften, Germany — [2]University of Leeds, Institute for Materials Research, United Kingdom — [3]University of Leeds, School of Physics and Astronomy, United Kingdom — [4]University of Duisburg-Essen, Faculty of Physics, Germany

Multiferroics are promising for sensor and memory applications. However, no single-phase material displaying both ferroelectricity and large magnetization at room-temperature has hitherto been reported. This situation has substantially been improved in the novel relaxor ferroelectric (BiFe0.9Co0.1O3)0.4-(Bi1/2K1/2TiO3)0.6, where polar nanoregions (PNR) transform into static-PNR (SPNR) and simultaneously enable congruent multiferroic clusters (MFC) to emerge from inherent Bi(Fe,Co)O3 rich regions. The MFC supposedly are ferrimagnetic. On these MFC, exceptionally large direct and converse magnetoelectric coupling coefficients, α * 1.0 x 10-5 s/m at room-temperature, were measured by PFM and MFM respectively. We expect the non-ergodic relaxor properties which are governed by the Bi1/2K1/2TiO3 component to play a vital role in the strong ME coupling. The extremely high Neel temperature of approx. 690 K, as verified by neutron diffraction, further underlines the exceptional magnetic properties of the material. This new class of non-ergodic relaxor multiferroics bears great potential for applications.

MA 38.4 Thu 10:30 H25

Imaging of electric-field-induced magnetization reversal in $Dy_{0.7}Tb_{0.3}FeO_3$ — •Ehsan Hassanpour Yesaghi[1], Yusuke Tokunaga[2], Thomas Lottermoser[1], Yasujiro Taguchi[3], Yoshinori Tokura[3,4], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, Zürich, Switzerland — [2]Department of Advanced Materials Science, University of Tokyo, Kashiwa, Chiba 277-8561, Japan — [3]RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan — [4]Department of Applied Physics and Quantum-Phase Electronics Center (QPEC), University of Tokyo, Tokyo 113-8656, Japan

Full control of the magnetic state via electric field was recently reported in $Dy_{0.7}Tb_{0.3}FeO_3$. This material undergoes several magnetic phase transitions, including a multiferroic phase in which the polarization is induced by the symmetric exchange interaction of the rare earth moments and Fe spins. It was shown that the magnetization reversal in this material depends on both the magnitude and the time-derivative of the electric field, such that the switching occurs only if the E-field is applied sufficiently fast. Such behavior, however, was never investigated at the level of domains, which is crucial for its understanding and application in devices. Here we investigate the underlying physics of the time-dependent switching process using Faraday imaging technique in order to spatially resolve magnetic domains and domain walls. The observation of two distinct types of domains and their relation to the magnetic Fe/Dy sub-lattices will be discussed. The electric field dependence on the magnetic ordering will be presented.

MA 38.5 Thu 10:50 H25

Influence of ferroelectric electron emission in BTO layer systems on measurements of core-level binding energies — •Paula Huth[1], Martin Welke[1], Alireza Bayat[2], Karl-Michael Schindler[2], Angelika Chassé[2], and Reinhard Denecke[1] — [1]Wilhelm-Ostwald-Institut, Universität Leipzig — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

Barium titanate (BTO) is a well-known ferroelectric material with perovskite-like structure. During the phase transition from tetragonal to cubic crystal system at 120 °C, the spontaneous electrical polarization vanishes. In conventional x-ray photoelectron spectroscopy measurements, sudden shifts ("jumps") in core-level binding energies have been observed at the Curie temperature. This was proposed to originate from surface charge build-up[1], but by using high-kinetic energy XPS, the effect could be shown to occur for deeper layers and in the presence of covering non-conducting oxide layers, as well. Since the effect occurs at the ferroelectric-to-paraelectric phase transition, ferroelectric electron emission[2] is proposed as origin. Iron and Cobalt layers of different thicknesses have been prepared in-situ on BTO(001), to show that the effect vanishes if a conducting layer is present. Such core-level shifts have been found for all elements in BTO, except in the presence of thick metal overlayers. Additionally, a general difference of the electronic binding energy between the tetragonal and the cubic phase has been observed and confirmed by DFT calculations. [1] L. Makhova et al.: Phys. Rev. B, 83 (2011) 11540. [2] G. Rosenman et al.: J. Appl. Phys., 88 (2000) 6109.

20 min. break

MA 38.6 Thu 11:30 H25

Kibble-Zurek mechanism in hexagonal $RMnO_3$ — •Quintin Meier[1], Andres Cano[2], and Nicola Spaldin[1] — [1]ETH Zürich, Department for Materials Theory, Zürich, Switzerland — [2]CNRS, Université de Bordeaux, ICMCB, UPR 9048, 33600 Pessac, France

We present a theoretical study of the effect of cooling rate on the ferroelectric domain formation in the multiferroic hexagonal manganites, RMnO3 (R is Y or a small rare-earth atom). The hexagonal manganites are of interest because of their unusual improper ferroelectricity, which allows multiferroism and promotes conducting domain walls. In addition, the associated structural phase transition has recently been shown to form topological defects according to the Kibble-Zurek scaling law [1], which describes the number of topological defects formed as a function of cooling rate. Here we investigate the Kibble-Zurek scaling for a range of compounds in the RMnO3 series by using first principles density functional theory to calculate trends in the scaling parameters. We present possible models that describe the experimentally observed deviations from Kibble-Zurek scaling at both very fast and very slow cooling rates.

[1] Griffin, S. M., Lilienblum, M., Delaney, K. T., Kumagai, Y., Fiebig, M., & Spaldin, N. A. (2012) Physical Review X, 2(4), 041022.

MA 38.7 Thu 11:50 H25

Theory of colossal magnetoelectric responses in Ni_3TeO_6 — •Sergey Artyukhin[1], Sang-Wook Cheong[2], and David Vanderbilt[2] — [1]Italian Institute of Technology, Genova, Italy — [2]Department of Physics and Astronomy, Rutgers University, USA

The manipulation of magnetic ordering with applied electric fields is of pressing interest for new spintronic and information storage applications. Recently, such magnetoelectric control was realized in multiferroics [1]. However, their magnetoelectric switching is often accompanied by significant hysteresis, resulting from a large barrier, separating different ferroic states. Hysteresis prevents robust switching, unless the applied field overcomes a certain value (coercive field). I will discuss the role of a switching barrier on magnetoelectric control, in particular, in a collinear antiferromagnetic and pyroelectric Ni_3TeO_6 [2,3]. The barrier between two magnetic states in the vicinity of a spin-flop transition is almost flat, and thus small changes in external electric/magnetic fields allow to switch the ferroic state through an intermediate state in a continuous manner, resulting in a colossal magnetoelectric response. This colossal magnetoelectric effect resembles the large piezoelectric effect at the morphotropic phase boundary in ferroelectrics.

[1] T. Kimura, T. Goto, H. Shintani et al., Nature 426, 5 (2003)
[2] Y.-S. Oh, S. Artyukhin J. J. Yang et al., Nature Communications 5, 3201 (2014)
[3] J. W. Kim, S. Artyukhin, E. D. Mun et al., Phys. Rev. Lett. 115, 137201 (2015)

MA 38.8 Thu 12:10 H25

Ab initio calculation of ARPES and SPLEED spectra for the multiferroic heterostructure Co/$BaTiO_3$ — •Stephan Borek[1], Jürgen Braun[1], Jan Minár[1,2], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]University of West Bohemia Pilsen

Multiferroic heterostructures possess promising properties concerning technical applications. It has been shown recently that the combination of x-ray absorption spectroscopy (XAS), x-ray magnetic circular dichroism (XMCD) and x-ray magnetic linear dichroism (XMLD) can be used to determine the magnetic properties of the Co surface layers of the multiferroic system Co/$BaTiO_3$ [1]. In this way an indirect investigation of the coupling mechanisms between the ferroelectric and the ferromagnetic materials gets possible. In our work we consider complementary spectroscopic methods which are suitable for the determination of the properties of multiferroic heterostructures. For this purpose we used the theoretical description of angle-resolved photoemission spectroscopy (ARPES) and spin-polarized low energy electron diffraction (SPLEED) to investigate the coupling mechanisms at the Co/BTO interface. We will show that both methods provide detailed insight into the behaviour of the electronic structure during a switching of the electric polarization of $BaTiO_3$.

[1] M. Hoffmann et al., Journal of Phys: Cond. Matter **27**, 426003 (2015)

MA 38.9 Thu 12:30 H25

Chaos and stochastic resonance during ferroelectric switching — •Martin Diestelhorst — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Von-Danckelmann-Platz 3, 06120 Halle, Germany

The Landau theory of second-order phase-transitions being taken into account, it gives motivation to look for effects like bifurcations, chaos and stochastic resonance in ferroelectrics. The main features of these effects may be understood based on the quartic double-well potential $V(x) = \frac{a}{2}x^2 + \frac{b}{4}x^4$, which is of the same form as the thermodynamic potential of a ferroelectric with second-order phase-transition near the Curie temperature. The predicted effects could be in principle found in ferroelectric TGS. It is shown that these effects are related to complicated regimes of domain switching and give rise to peculiarities which may not be understood in terms of the simple double-well potential. These effects must be attributed to the real processes which occur during switching.

MA 39: Magnetic Particles

Time: Thursday 9:30–13:15 Location: H31

MA 39.1 Thu 9:30 H31

Wechselwirkung magnetischer, hydrodynamischer und thermodynamischer Kräfte und die Dynamik von suspendierten Mikropartikel: Selbstorganisation und Anwendungen — •Claus Fütterer — Biophysical Tools GmbH/Forschung, 04317 Leipzig, Germany

Superparamagnetische Mikro- und Nanopartikel haben rasch zahlreiche Einsatzmöglichkeiten in der Biophysik, der Biotechnologie und Materialforschung gefunden. Insbesondere die Aufreinigung von Molekülen und Zellen ist heute so einfach wie nie zuvor und der Automatisierung zugänglich gemacht worden. Die Möglichkeiten sind damit jedoch bei Weitem noch nicht ausgeschöpft.

Das einzigartige Kleeblatt-Potential mit positiven und negativen Anziehungszonen suspendierter Partikel in Wechselwirkung mit hydrodynamischen Feldern sowie thermodynamischen Fluktuationen ist nicht nur verantwortlich für eine ungewöhnlich dynamische Selbstorganisation von Mikrostrukturen (Aggregation und Separation), sondern auch für neue Anwendungen wie zum Beispiel die massiv parallele Untersuchung von Wechselwirkungsdynamiken von Einzelmolekülen in hoher Präzision. Hierzu werden ein Abriss der Theorie, experimentelle Daten sowie Perspektiven für mögliche zukünftige Anwendungen präsentiert.

MA 39.2 Thu 9:45 H31

Structural and magnetic properties of self-assembled 3D nanoparticle macrocrystals — •Michael Smik, Genevieve Wilbs, Elisa Volkmann, Emmanuel Kentzinger, Jörg Persson, Ulrich Rücker, Oleg Petracic, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich

We have used centrifuge assisted sedimentation to fabricate 3D nanoparticle 'macrocrystals' from commercially available spherical iron oxide nanoparticles. The assembly of macrocrystals up to 300 μm in size was possible. The samples were characterized using scanning electron microscopy, which allowed for the identification of single crystals, which could then be isolated for further study. Using small angle x-ray scattering (SAXS) using the new in-house instrument 'GALAXI' (Gallium Anode Low-Angle X-ray Instrument) the supercrystalline structure could be identified to be face-centered cubic. The magnetic structure was investigated by a variety of magnetometric methods, including zero field cooled and field cooled curves, thermo remanent and isothermal remanent magnetization, as well as ac susceptibility. All methods hint toward a spin-glass-like structure, however, deviations from the expected results for a spin-glass indicate a novel kind of magnetic ordering.

MA 39.3 Thu 10:00 H31

Strain and Electric Control of Magnetism in Supercrystalline Iron Oxide Nanoparticle - BaTiO3 composites — •Liming Wang[1], Oleg Petracic[1], Emmanuel Kentzinger[1], Ulrich Rücker[1], Alexandros Koutsioumpas[2], Stefan Mattauch[2], 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, n, Lichtenbergsrtr. 1, Graching

The manipulation of magnetism of self-assembled iron oxide nanoparticle (NP) monolayers on top of BaTiO3 (BTO) single crystals is reported. We observe strain induced magnetoelectric coupling (MEC) as shown by measurements of both the magnetization and magnetoelectric ac susceptibility (MEACS). The magnetization, coercivity, remanent magnetization and MEACS signal as function of temperature shows abrupt jumps at the BTO phase transitions temperatures. A magnetic "hardening effect" is observed with variation of strain or electric field. Grazing incident small angle X-ray scattering (GISAXS) and scanning electron microscopy (SEM) confirms a hexagonal close-packed supercrystalline order of the NP monolayers.

MA 39.4 Thu 10:15 H31

GMR sensors for detection of magnetic nanoparticles in lubricants — •Thomas Rempel, Martin Gottschalk, and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, PB 100131, D-33501 Bielefeld, Germany

Magnetic nanoparticles are growing of technological interest and show beneficial characteristics in a wide field of applications. One emerging field of application is the use of magnetic nanoparticles in lubricants to e.g. tune the lubricant's friction coefficient. As particle concentration and agglomeration influence the lubricants properties, an on-site quality control device is necessary for real life application. We demonstrate our first approach based on a GMR sensor to face these challenges. Therefore, serpentine shaped sensors are fabricated by lithographic methods on which solvents with magnetic nanoparticles are placed. The sensor's response will be discussed for different geometries. To characterize the particle dispersion and agglomeration inside the lubricant, microscopic techniques with resolutions on the nanometer length scale are necessary. We present an approach to get an insight of the nanoparticle distribution and agglomeration with a dual beam focused ion beam (FIB) and a scanning electron microscope.

MA 39.5 Thu 10:30 H31

Ultra high magnetic anisotropy in octapod shaped iron oxide nanoparticles — •P Anil Kumar[1,2], Gurvinder Singh[3], Joachim Landers[1], Giuseppe Muscas[4,5], Davide Peddis[5], Heiko Wende[1], and Roland Mathieu[2] — [1]Faculty of Physics and CENIDE, University of Duisburg - Essen, Duisburg 47048, Germany — [2]Department of Engineering Sciences, Uppsala University, 751 21 Uppsala, Sweden — [3]Department of Materials Science and Engineering, NTNU, N-7491, Trondheim, Norway — [4]Department of Physics, Uppsala University, 751 21 Uppsala, Sweden — [5]ISM-CNR, Area della Ricerca, C.P. 10-00016 Monterotondo Scalo, Roma, Italy

The shape of the magnetic nanoparticles is known to effect the magnetic anisotropy of the particles apart from the surface anisotropy. Here, we present results of macroscopic magnetic measurements and Mössbauer spectroscopy on octapod shaped Fe_3O_4 nanoparticles (of $\sim$ 20 nm size) obtained by controlling the growth of selective crystal orientations. These octapod particles show a distinct superparamagnetic transition indicative of a narrow size distribution. Interestingly, the isothermal magnetic hysteresis loops measured at 5 K and up to a field of 9 T are unconventional of any iron oxide system. The hysteresis loop remains open and the magnetization is unsaturated even up to 9 T field, indicating a very high magnetic anisotropy of these particles. Temperature dependent and in-field Mössbauer spectroscopy analysis also supports the inferences drawn from the macroscopic magnetic measurements. We will discuss possible reasons for such a high magnetic anisotropy in these particles.

MA 39.6 Thu 10:45 H31

Theory of nano-spintronic logic functionalities on a Ni_4 cluster — •Wolfgang Hübner, Georgios Lefkidis, and Debapriya Chaudhuri — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67653 Kaiserslautern, Germany

Starting from high level, *ab initio* calculations, we present several new all-spin-based nano-logic functionalities, which require a minimum of four active magnetic centers. The underlying mechanisms for all operations are coherent Λ processes, driven by suitably tailored laser pulses.

Our calculations indicate, that in the geometrically optimized Ni_4 cluster the spin density exhibits a high degree of localization. In addition to ultrafast (90 fs) optically triggered *local spin flips* and *spin transfers*, which require only one or two atomic magnetic centers, we demonstrate the following operations with sufficiently high fidelity: spin bifurcation and its reverse (spin association/ merging), as well as the *which path* interference. We construct two nano-logic elements: a 4-bit cyclic SHIFT register [1] and a pure-spin OR gate [2]. The former depends on the appropriate combinations of the spin transfer scenarios whereas the latter depends on the *spin association.* The *which path* interference employs the phase of the final spin state of a two-step spin transfer process which depends on the exact path traveled by the spin.

The scenarios provide the necessary basic functionalities for nanologic applications.

[1] G. D. Mahan, Phys. Rev. Lett. **102**, 016801 (2009).
[2] D. Chaudhuri, University of Kaiserslautern, Ph.D. Thesis (2016).

15 min. break

MA 39.7 Thu 11:15 H31

Experimental investigation of the spin structure in MnO nanoparticles, powder and single crystal — •Xiao Sun[1], Alice Klapper[1], Yixi Su[2], Kirill Nemkovski[2], Oskar Köhler[3], Heiko Bauer[3], Anna Schilmann[3], Wolfgang Tremel[3], 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]Jülich Centre for Neutron Science JCNS at Heinz Maier-Leibnitz Zentrum MLZ, Forschungszentrum Jülich GmbH, Garching — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, Mainz

We have studied the magnetic spin structure of antiferromagnetic (AF) MnO nanoparticles (NPs), powder and single crystal using both magnetometry and polarized neutron scattering. MnO NPs show a peculiar peak at low temperatures (ca. 25K) instead at the Néel temperature of 120K in the magnetization curves. However, polarized neutron scattering results show the expected behavior of the AF order parameter of MnO. For MnO powder and single crystal, features at both the low temperature and Néel temperature have been found in magnetometry. A phase transition at the peak temperature in the MnO single crystal has been observed in neutron scattering. This peak temperature matches the Tc of Mn2O3 or Mn3O4. We conclude that the magnetic behavior of MnO NPs can be explained by a superposition of superparamagnetic-like thermal fluctuations of the AF Néel vector inside an AF core and a strong magnetic coupling to a FM Mn2O3 or Mn3O4 shell.

MA 39.8 Thu 11:30 H31

Strain analysis with atomic resolution at FePt-substrate interfaces — •S. Wicht[1,2], S. H. Wee[3], O. Hellwig[3], D. Weller[3], and B. Rellinghaus[1] — [1]IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany. — [2]TU Dresden, IFWW, D-01062 Dresden, Germany. — [3]HGST, 3403 Yerba Buena Rd, San Jose, CA-95135, USA.

Highly textured $L1_0$-ordered FePt films are foreseen to overcome the performance of state of the art CoCrPt based perpendicular media and achieve storage densities beyond 1.5 TBit/in^2. A crucial criteria to develope the full potential of the film is a distinct (001) texture of the $L1_0$ phase. The common way to achieve an out-of-plane (oop) texture is to growth FePt epitaxially on an appropriate seed layer, namely MgO. MgO, however, causes some drawbacks like a poor wetting behavior of FePt and a certain misalignment of the easy axis orientation. To further investigate this phenomenon and the influence of the lattice mis-

match between the unit cells of FePt and the substrate, discontinuous FePt films are grown on single crystals of (La, Sr)(Al, Ta)O_3, $SrTiO_3$, $MgAl_2O_4$ and MgO. The FePt films exhibit mainly oop textured islands. Nevertheless, undesired fractions of $L1_2$-ordered and in-plane oriented crystals are occur at reduced lattice mismatches. Quantitative HRTEM analyses reveal that enhanced lattice mismatches are accompanied by an increased density of dislocations at the interface, which goes along with a broadened FePt (002) rocking curve. The correlations of these findings will be discussed within the presentation.

MA 39.9 Thu 11:45 H31

Solid state NMR - a powerful tool to characterize magnetic nanoparticle assemblies — •Franziska Hammerath[1,2], Markus Gellesch[2], Maik Scholz[2], Rasha Ghunaim[2], Maria Eleni Belesi[2], Alexey Alfonsov[2], Heike Schlörb[2], Silke Hampel[2], Sabine Wurmehl[2], and Bernd Büchner[2] — [1]Institute for Solid State Physics, Dresden Technical University, TU Dresden, 01062 Dresden, Germany — [2]IFW Dresden, Institute for Solid State Research, PF 270116, 01171 Dresden, Germany

We present nuclear magnetic resonance (NMR) measurements on magnetic nanoparticles, most of them synthesized inside carbon nanotubes, with unary, binary and ternary precursor conditions. Our studies on Co, Fe, CoFe, CoGa, Co_2FeGa and Mn_3O_4 nanoparticles show that nuclear magnetic resonance is the method of choice to identify and quantify different chemical compositions, local environments and crystallographic structures of intermetallic magnetic nanoparticle assemblies. Advantages of this method compared to standard characterization methods such as powder X-ray diffraction or TEM-EDX will be discussed.

MA 39.10 Thu 12:00 H31

SmCo nanoparticles from the gas-phase: On the stability of intermetallic $SmCo_5$ at the nanoscale. — •Frank Schmidt[1,2], Ludwig Schultz[1], and Bernd Rellinghaus[1] — [1]IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany — [2]TU Dresden, IFWW, D- 01062 Dresden, Germany

$SmCo_5$ is among the magnetic materials with the highest magnetocrystalline anisotropies and Curie temperatures, T_C, respectively. The latter are indispensable for high temperature applications, where $Nd_2Fe_{14}B$ can no longer be used. In the present study, we investigate the formation and phase stability of SmCo nanoparticles from the gas phase, which could serve as a model system for their (nanostructured) bulk counterparts. Particular attention is paid to the question, if the intermetallic phase $SmCo_5$ (or one of its derivates) forms in particles with only a few nanometer in size, which grow without contact to any solid or liquid matrix in a low pressure Ar atmosphere. This question is closely related to the possible occurrence of segregation that is frequently observed in nanoscale materials and that goes along with a deterioration of the magnetic properties. Aberration-corrected transmission electron microscopy is used in combination with spectroscopic methods to determine the local structure and the chemical composition. It is found that, depending on the phase formation temperature, SmCo nanoparticles tend to de-mix. The magnetic properties of the particle ensembles, as determined from VSM measurements, are correlated with the predominant core-shell structure of the SmCo particles.

MA 39.11 Thu 12:15 H31

Superparamagnetic Response from Nanoparticles in Splenic Macrophages — •Ulf Wiedwald, Marina Spasova, Anna Elsukova, and Michael Farle — Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

We have identified that murine spleen macrophages harbor an enormous amount of endogenous nanoparticles with monodisperse crystal size and unexpected superparamagnetic properties [1]. It is well established that macrophages contain the 12 nm disk-shaped protein ferritin with an 8 nm cage that can buffer up to 4500 iron atoms in the form of the antiferromagnetic compound ferrihydrite [2]. Although the diameter and iron content identified by transmission electron microscopy support the presence of ferritin, the strong magnetic response is incompatible with the nature of ferrihydrite. We characterized these nanoparticles form splenic macrophages by SQUID magnetometry and found an average magnetic moment of $8600\mu_B$ per particle in the superparamagnetic state at T = 300 K. This indicates the presence of magnetic phases different from the expected antiferromagnetic ferrihydrite. As a result, the intrinsic superparamagnetism of splenic macrophages contaminates cell isolates in magnetic cell separation [1]. This work is a collaboration with the Institute of Experimental Immunology, University of Bonn, Germany.

[1] L. Franken et al., Scientific Reports 5, 12940 (2015).
[2] P. M. Harrison et al., Adv. Inorg. Chem. 36, 449 (1991).
[3] S. Gider et al., Science 268, 77 (1995).

MA 39.12 Thu 12:30 H31

Positioning and Detection of Magnetic Nanoparticles for Lab-on-Chip systems — •Benjamin Riedmüller, Shalini Easwardas, Florian Ostermaier, and Ulrich Herr — Institute für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland

Magnetic nanoparticles are interesting in combination with magneto-resistive sensors for Lab-on-Chip systems. In such applications, superparamagnetic particles are typically used, to which biological analytes can be specifically bound. By detecting the particles, the presence of the bio-species can be confirmed. For detection, the particles have to be positioned in the vicinity of the active sensor area. Here, a common principle for positioning of superparamagnetic particles is the application of magnetic field gradients by which a force on the particles is generated. In a previous work we derived a quantitative model for the force on a superparamagnetic particle by a combination of the field gradient produced by tapered conductor lines and a superimposed, homogeneous magnetic field. By this, the limitation by which particles can only be attracted towards the conductor is overcome. We demonstrated that this approach allows positioning a single superparamagnetic particle in two dimensions on length scales > 100 um with a precision of < 1 um. Based on this technique a particle lens consisting of a conductor ring can be constructed by which a single particle is first guided and then fixed at a pre-defined position with high accuracy. Our results further show that these manipulation concepts can be easily combined with common micro-structured magneto-resistive sensors which allow the real-time detection of the motion of the particle.

MA 39.13 Thu 12:45 H31

Magnetically patterned rolled-up exchange bias tubes: A paternoster for superparamagnetic beads — •Timo Ueltzhöffer[1], Robert Streubel[2,3], Iris Koch[1], Dennis Holzinger[1], Denys Makarov[2,4], Oliver G. Schmidt[2,5], and Arno Ehresmann[1] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel (Germany) — [2]Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstrasse 20, 01069 Dresden (Germany) — [3]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720 (USA) — [4]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden (Germany) — [5]Technische Universität Chemnitz, Strasse der Nationen 62, 09111 Chemnitz (Germany)

Artificially engineered parallel stripe magnetic domains in exchange bias layer systems were rolled-up into tubular architectures with azimuthally aligned magnetic domain patterns.[1] These objects were used for a paternoster-like transport of superparamagnetic beads through and above the tube by applying periodic pulse sequences of very weak external magnetic fields. This approach paves the way towards novel perspectives and applications in biotechnology, including particle transport related phenomena and lab-on-a-chip devices.

[1] Schmidt, O.G. and Eberl, K. Nanotechnology: Thin solid films roll up into nanotubes. Nature 410, 168 (2001).

MA 39.14 Thu 13:00 H31

ferromagnetic resonance spectroscopy of magnetotactic bacteria — •Sara Ghaisari[1], Stefan Klumpp[2], and Damien Faivre[1] — [1]Max Planck Institute of Colloids and Interfaces — [2]Institut für Nichtlineare Dynamik, Georg-August-Universität Göttingen

Magnetotactic bacteria (MTB) are micro-organisms capable of forming intracellular magnetic nanoparticles inside vesicles called magnetosomes. Magnetosomes consist of a lipid membrane surrounding a ferromagnetic crystal, which is magnetite Fe3O4 or greigite Fe3S4. The size of the particles (40-100 nm) provides the organisms with a permanent magnetization. In addition, these particles are arranged into a chain such that their dipole moments add up, resulting in a strong enough magnetic moment to get aligned in the Earth*s magnetic field. Due to these unique magnetic and morphology properties, magnetosome particles are attracting interests in many interdisciplinary areas. One key advantage is the strong uniaxial anisotropy and restricted direction of magnetization. Ferromagnetic Resonance (FMR) is a powerful tool for determining the magnetic anisotropies of a ferromagnetic material. Here, we use FMR to investigate and characterize magnetosomes in different strains of magnetotactic bacteria. Different spectra are observed for different strains that can be correlated to the organization of particles and crystalline structure observed by electron microscopy. Simulations of the FMR spectra using an ellipsoid model and their quantitative comparison with the experimental spectra are used to interpret different magnetic parameters and their effect on the spectrum.

MA 40: Focus: Terahertz radiation and magnetism

Organized by M. Kläui (U. Mainz) and P. M. Oppeneer (Uppsala University)

Magnetization dynamics has been studied intensively with pump-probe magneto-optical spectroscopy, in which an ultrashort infrared laser pulse is used to excite the electrons in a material and subsequently trace the magnetization dynamics using the probe pulse. Ultrashort pulses in the terahertz regime (frequencies of 1 - 20 THz) have only recently become available. Since THz radiation has typical energies that match those of the fundamental low-energy excitations in solids, such as phonons and magnons, it can ideally be employed to excite these directly, without exciting the electron system first. Consequently, THz radiation experiments have recently begun to unlock new insight in ultrafast magnetic processes, either by using THz radiation as a pump or as a tool to analyze the spin and charge dynamics. This Focused Session is dedicated to highlighting the emerging opportunities to employ THz radiation in magnetism research and to underline the novel fundamental insight that THz experiments have recently provided.

Time: Thursday 9:30–11:45 Location: H32

Invited Talk MA 40.1 Thu 9:30 H32
Sub-cycle terahertz electronics and magnonics: control and nanoscopy — •Rupert Huber — Department of Physics, University of Regensburg, 93053 Regensburg, Germany

High-intensity terahertz (THz) sources have become a unique tool to explore condensed matter under atomically strong electric and magnetic biasing. We show that terahertz fields of up to 11 GV/m can accelerate electrons in bulk semiconductors to perform complete Bloch oscillation cycles within half an oscillation period of the drive field. The concomitant magnetic field component allows us to control spins in magnetically ordered solids. Intense THz pulses drive the spin degree of freedom into a massively nonlinear response regime. By combining scanning probe microscopy with phase-locked high-field THz waveforms and field-sensitive electro-optic sampling, we unite sub-cycle time resolution with nanometer and even atomic-scale spatial resolution. Our results shed fundamentally new light onto the structure and dynamics of the elementary building blocks of condensed matter and spark hope for electronics and magnetic storage at optical clock rates.

Invited Talk MA 40.2 Thu 10:00 H32
Probing and controlling ultrafast magnetism with terahertz electromagnetic pulses — •Tobias Kampfrath — Fritz Haber Institute, Berlin, Germany

Sub-picosecond terahertz (THz) electromagnetic pulses are not only capable of probing and even controlling numerous low-energy excitations such as phonons, excitons and Cooper pairs but they also provide novel access to ultrafast magnetism.

As a first example, we optically launch ultrafast spin transport and study its conversion into charge currents by means of the inverse spin Hall effect [Nature Nanotech. 8, 256 (2013)]. Our approach allows us to monitor ultrafast spin currents, provides a quick and easy estimate of the strength of the spin Hall effect and leads to new and efficient emitters of THz pulses that fully cover the range from 1 to 30 THz without gap [http://arxiv.org/abs/1510.03729]. Second, we probe spin-lattice coupling by selective excitation of optical phonons in the model ferrimagnetic insulator yttrium iron garnet. A magnetization quenching on a time scale as short as 1 ps is found, attesting to a highly efficient equilibration of lattice and spins. We present a new microscopic mechanism of phonon-to-magnon conversion that provides a quantitative explanation of our experimental findings.

The results shown here were obtained in close collaborations with the research groups of L.M. Hayden, M. Kläui, Y. Mokrousov, M. Münzenberg, P.M. Oppeneer, A. Paarmann, I. Radu and D. Turchinovich.

15 min. break

Invited Talk MA 40.3 Thu 10:45 H32
THz Spintronics: Magnetotransport and Magnonics — •Zuanming Jin[1,2], Mathias Kläui[3], Tobias Kampfrath[4], Guohong Ma[2], Mischa Bonn[1], and Dmitry Turchinovich[1] — [1]Max Planck Institute for Polymer Research,Mainz,Germany — [2]Department of Physics,Shanghai University,Shanghai,China — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz,Mainz,Germany — [4]Fritz Haber Institute of the Max Planck Society,Berlin,Germany

Spin-dependent conduction in metals underlies all modern magnetic memory technologies, such as giant magnetoresistance (GMR). According to the fundamental Mott model, the charge current in ferromagnetic transition metals is carried by non-mixing populations of sp-band Fermi-level majority- and minority-spin electrons, experiencing spin-dependent momentum scattering with localized electrons originating from the spin-split d-band. The direct observation of magneto transport under such fundamental conditions, however, requires the conductivity measurements on the ultrafast, sub-100 fs timescale, at which the electron momentum scattering occurs. Here, using ultrafast terahertz spectroscopy on a GMR spin-valve, we directly observe the magneto transport in a metallic system under the fundamental conditions of Mott model. As a result, we are able to directly determine the fundamental parameters of magneto-transport - spin-dependent densities and momentum scattering times of conduction electrons in a ferromagnetic metal. Further, we will discuss the direct excitation, observation, and coherent control of THz-frequency magnons in rare-earth orthoferrites.

Invited Talk MA 40.4 Thu 11:15 H32
Precessional spin motion and magnetization quenching induced by intense Terahertz pulses — •Christoph Hauri — SwissFEL, Paul Scherrer Institute, 5232 Villigen-PSI, Switzerland

Laser pulses in the low-frequency Terahertz range ($1-15$ THz) with field strength up to several GV/m and several Tesla have become available only very recently. Such pulses offer novel opportunities to explore ultrafast magnetization dynamics and magnetic domain switching in a regime differing from the commonly used optical lasers where the magnetization control is mediated by heat deposition. We show that strong THz fields allow coherent spin excitation even without exciting a magnetic mode (e.g., magnon). Our investigations on cobalt, nickel and iron thin films unravel the onset of a co-existence of precessional motion and ultrafast magnetization quenching as function of the THz field strength. While the coherent precessional motion is induced by the magnetic field the concomitant electric field component gives rise to fast demagnetization. Our findings illustrate the fundamental limits of metallic ferromagnetic thin films in view of magnetic switching by THz fields.

MA 41: Magnetic Coupling Phenomena

Time: Thursday 9:30–12:00 Location: H33

MA 41.1 Thu 9:30 H33

X-ray absorption studies of FeMn/Co exchange-bias systems
— •Mathias Schmidt, Patrick Audehm, Gisela Schütz, and Eberhard Goering — Max-Planck-Institut für Intelligente Systeme

Exchange-bias (EB) systems play an important role for several applications in magnetic storage techniques and spintronics. Among those materials, FeMn/Co thin films are one of the most prominent examples due to their high coupling strength at the interface leading to a distinct unidirectional asymmetry of the hysteresis loop after field cooling. We used molecular beam epitaxy (MBE) to produce FeMn/Co systems on (100) oriented MgO substrates.

On these samples, we performed X-ray absorption (XAS) measurements making use of the X-ray circular magnetic dichroism (XMCD) to analyze the element-specific contributions to the uncompensated rotatable part of the magnetic moments close to the antiferromagnetic/ferromagnetic interface. Besides the well-known contribution of the Fe atoms to the uncompensated rotatable part we also found a notable amount of rotatable Mn moments. Additionally, we performed a quantification of the contributions of orbital and spin magnetic moments using the well-known sum rules. Finally, we were able to estimate the effective thickness of the uncompensated rotatable part of the AF layer proving that in deed a considerable part of the AF layer (up to 20% of the total thickness) is coupled to the Co layer on top in a ferromagnetic way. This experimental result is in contradiction to several theoretical models used for describing the EB, where the AF layer is mostly considered to be magnetically rigid.

MA 41.2 Thu 9:45 H33

Tailoring the magnetic moment of Fe/3d metal/Gd trilayers by varying thenumber of 3d transition metal spacer layers —
•Dirk Walecki[1], P. Anil Kumar[1], Samira Webers[1], Carmine Autieri[2], Mark Gubbins[3], Biplab Sanyal[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Department of Physics and Astronomy, Uppsala University, Sweden — [3]Seagate Technology, Springtown Industrial Estate, Derry, UK

We investigate the magnetic coupling between ultrathin Fe and Gd layers via an anti- or non-magnetic spacer layer by means of conventional magnetometry methods. Interlayer exchange coupling in alternating ferromagnetic/non-magnetic superlattice structures was explored extensively in the past but there is only little known about the coupling behaviour between high-moment lanthanides and 3d transition metals with high Curie temperatures. A ferromagnetic coupling between Fe and Gd has already been established in 2010 by employing five monolayers of Cr as interlayer [1]. Following up these results we employed Sc and Mn as a spacer material to mediate the coupling between Fe and Gd. Since the theory predicts short-period oscillations to occur, a high accuracy in preparing the trilayers is required. For this purpose we make use of a molecular beam epitaxy system.

[1] B. Sanyal et al., Phys. Rev. Lett. 104, 156402 (2010)

MA 41.3 Thu 10:00 H33

Antiferromagnetism in ordered and disordered full Heusler compounds —
Eszter Simon, György J. Vida, András Deák, Sergii Khmelevskyi, and •László Szunyogh — University of Technology and Economics, Budapest, Hungary

The growing technological demand for spintronics applications raised increased interest for searching novel antiferromagnets (AFM). Promising candidates are the full Heusler compounds like Ni2MnAl in the B2 phase or Ru2MnZ (Z= Si, Ge) having Néel temperature above the room temperature. In this contribution we present a study of these alloys based on first-principles calculations of interatomic Mn-Mn exchange interactions. Chemical disorder is taken into account in terms of the coherent potential approximation. By setting up a suitable Heisenberg spin model we performed Monte Carlo simulations of the magnetic properties at finite temperature.

In case of Ru2MnSi, our numerical results suggest that suppressing the intermixing between the Mn and Si atoms, the Néel temperature can potentially be increased by more than 30% [1]. For Ni2MnAl, a systematic study from the ordered L21 to the disordered B2 phase shows a progressive change from the FM state to a fully compensated AFM state, due to strong AFM site-antisite Mn-Mn interactions [2].

As an input for the study of potential exchange bias effects, we also present calculated spin-model parameters for the interface between these Heusler alloys and bcc Fe.

[1] S. Khmelevskyi et al., Phys. Rev. B 91, 094432 (2015)
[2] E. Simon et al., Phys. Rev. B 92, 054438 (2015)

MA 41.4 Thu 10:15 H33

Exchange bias in epitaxial and polycrystalline thin film Ru_2MnGe / Fe bilayers —
•Jan Balluff[1], Markus Meinert[1], Jan-Michael Schmalhorst[1], Günter Reiss[1], and Elke Arenholz[2] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, USA

We report on thin film bilayers of the antiferromagnetic Heusler compound Ru_2MnGe and Fe, as well as the resulting exchange bias at low temperatures and its temperature dependence. Due to the Ru_2MnGe Néel temperature of 358K they may be valuable for potential applications in the field of spintronics. Epitaxial Ru_2MnGe / Fe bilayers show exchange bias up to 680 Oe at 3 K. Furthermore, we grew polycrystalline Ru_2MnGe showing exchange bias of the same order. Improvements have been achieved by interface doping with Mn, which increases the exchange bias by about 40% for polycrystalline samples. We discuss the differences between the epitaxial and polycrystalline films using X-ray absorption and depth analysis techniques.

MA 41.5 Thu 10:30 H33

Searching for exchange bias in Heusler alloys —
•Rocio Yanes[1], Eszter Simon[2], Laszlo Szunyogh[2], and Ulrich Nowak[1] — [1]Universität Konstanz, Konstanz, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary

The exchange bias (EB) effect is a unidirectional anisotropy of a magnetic system, related to the coupling between a ferromagnet (FM) and an antiferromagnet (AF). The EB effect is used in multiple magnetic devices to stabilize the magnetization as in GMR sensors, magnetic tunnel junctions etc. This fact has increased the demand of AF and it has led to an increased interest for novel AF materials with Néel temperature above room temperature, being Heusler alloys (HA) promising candidates for that.

In this work we studied the magnetic properties of a series of HA/FM bilayers using a multiscale modeling, linking ab initio calculations with dynamical spin model simulations [1]. This technique provides us a direct knowledge of the exchange interactions at the AF/FM interface.

In order to check the possible existence of EB effect, numerical calculations of the hysteresis loops of: Ni2MnAl(B2)/FM bilayers (FM=Co and Fe) were carried out for different values of the thickness of the AF substrate (t_{AF}). Our preliminary results indicate that for perfect Ni_2MnAl/FM bilayers there is no (in-plane) EB effect. However, when chemical disorder is included in the AF layer a small EB appears.

[1] L. Szunyogh et. al, Phys. Rev. B, 83,024401 (2011).

15 min. break

MA 41.6 Thu 11:00 H33

Magnetic Property Modification of the Ferromagnet in Exchange Bias Systems by Low Energy Helium Ion Bombardment —
•Henning Huckfeldt[1], Dennis Nissen[2], Manfred Albrecht[2], and Arno Ehresmann[1] — [1]Institute for Physics and Center for Interdisciplinary Nanoscience and Technology (CINSaT), Kassel University, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Institute for Physics, Augsburg University, Universitätsstrasse 1 Nord, 86159 Augsburg, Germany

Using ion bombardment induced magnetic patterning (IBMP)[1] it becomes feasible to create magnetic structures that can be used in lab-on-a-chip devices, e.g. for fluid mixing.[2] During their preparation, exchange bias (EB) layer systems are locally exposed to 10 keV Helium ions while an external magnetic field saturates the sample. Due to the energy deposited into the material by the ions, magnetic domain patterns with arbitrary magnetization orientation and strength can be created.[1] Even though this technique has been used for about a decade, the link between energy input and the change in the magnetic properties is not fully understood.

Experimental studies will be presented, showing the influence of structural defects created by the penetrating ions on the exchange bias field direction and magnitude as well as on the saturation magnetization.

[1] D. Engel *et al.*, *J. Magn. Magn. Mat. 293* (2005) 849.
[2] D. Holzinger *et al.*, *J. Appl. Phys. 100* (2012) 153504.

MA 41.7 Thu 11:15 H33

New insides in Co/FeMn exchange Bias system with detailed XMCD — •Patrick Audehm, Mathias Schmidt, Gisela Schütz, and Eberhard Goering — Max-Planck-Institute for Intelligent Systems

The Co/FeMn exchange Bias system is a wildly studied bilayer system. For the better understanding of the magnetic behavior of the magnetic moments, both spin and orbital character, at the interface, we used XAS (x-ray absorption spectra) and XMCD (x-ray magnetic circular dichroism). One advantage of these measurement techniques is the separation of element specific magnetic moments in spin and orbital contributions at the interface of a bilayer. We used our own dedicated "ERNSt" endstation at BESSY II, which is by purpose a reflectometer and therefore capable of very precise angle dependent measurements, so we are in the rare position to separate rotatable from non-rotatable magnetic moments in the antiferromagnet of the exchange bias system. We present here Fe based XMCD sum rule results. We surprisingly found a different field dependent behavior between spin and orbital moments. While the rotatable moments are spin dominated, the non-rotatable magnetic moments are of nearly pure orbital character. We also estimated the effective rotatable and pinned moment thicknesses at the interface. The founding in this very special system shows a way to a much broader impact for many magnetic systems.

MA 41.8 Thu 11:30 H33

Magneto-electronic coupling in modulated defect-structures of natural $Fe_{1-x}S$ — •Dimitrios Koulialias[1,2], Jörg F. Löffler[2], Andreas U. Gehring[1], and Michalis Charilaou[2] — [1]Institute of Geophysics, Department of Earth Sciences, ETH Zurich — [2]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich

Pyrrhotite (Fe_7S_8) is a major magnetic remanence carrier in the Earth's crust and in extraterrestrial materials, and its magnetic and electronic properties have initiated a large number of experimental and theoretical studies since more than a century. Despite the intense research efforts, there is still a lack of understanding of the low-temperature transition that is observed in natural samples. Importantly, it is not known whether the origin of the transition is structural or magnetic. We will provide compelling evidence that the low-temperature transition is a phenomenon caused by magnetic coupling between epitaxially intergrown superstructures. The two superstructures differ in their defect distribution, and consequently in their magnetic anisotropy. At $T < 30$ K, the magnetic moments of the superstructures become strongly coupled, resulting in a 12-fold anisotropy symmetry, which is reflected in the anisotropic magnetoresistance.

MA 41.9 Thu 11:45 H33

Reversible control of magnetism in $La_{1-x}Sr_xMnO_3$/ionic liquid systems — •Alan Molinari, Philipp Leufke, Christian Reitz, Subho Dasgupta, Robert Kruk, and Horst Hahn — Karlsruhe Institute of Technology (KIT), Institute of Nanotechnology (INT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Reversible control of magnetism by means of an electric field is a promising route for the realization of novel-low power consumption magnetic storage devices. In the last years intensive research studies have been performed on magnetoelectric systems, such as ferroelectric/ferromagnetic heterostructures, where the coupling at the interface was found to be responsible for reversibly controlling the magnetic response.

In our studies we have followed an alternative approach combining a thin film of $La_{1-x}Sr_xMnO_3$ (LSMO), a half-metallic complex oxide with a Curie temperature above room temperature, with an ionic liquid (DEME-TFSI) in a capacitor-like geometry. The interface coupling mechanisms, related to the formation of a Helmholtz double layer affecting the LSMO surface charge concentration and therefore the magnetic properties, have been investigated by means of in situ SQUID-cyclic voltammetry measurements as a function of temperature and applied potential.

MA 42: Magnetic Heuslers, Half-Metals and Oxides (jointly with TT)

Time: Thursday 9:30–12:30 Location: H34

MA 42.1 Thu 9:30 H34

Singular manifestation of square-planar geometry and novel $S=\frac{3}{2}$ state of a iridate Na_4IrO_4 — •Sudipta Kanungo[1], Binghai Yan[1,2], Patrick Merz[1], Claudia Felser[1], and Martin Jansen[3] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, 01187, Dresden, Germany — [3]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart, Germany

Local environments and valence electron counts primarily determine the electronic states and physical properties of transition metal complexes. For example, square-planar surroundings found in transition oxometalates such as curprates, Nickaltes are usually associated with the d^8 or d^9 electron configuration. In this work, we address an experimentally observed exotic square-planar mono-oxoanion $[IrO_4]^{4-}$ in Na_4IrO_4 with Ir(IV) in d^5 ($S=\frac{3}{2}$ state) configuration, using ab-initio calculations. On contrary, in its 3d counterpart, Na_4CoO_4, Co(IV) is in tetrahedral coordination with $S=\frac{5}{2}$ high spin state. Our ab-initio calculations reveal that the on-site Coulomb interaction U is the essential factor for determining the stability of the local coordination as well as spin state. We find that due to weak Coulomb repulsion of Ir-5d electrons, Na_4IrO_4 form in a square-planar coordination whereas for Na_4CoO_4, Co(IV) is in tetrahedral coordination, due to strong electron correlation at 3d Co site. Following the trend from 5d to 3d, we predict that the intermediate 4d material Na_4RhO_4, if synthesized, may favor tetrahedral coordination but with an $S=\frac{1}{2}$ low spin state.

MA 42.2 Thu 9:45 H34

Influence of extended crystal defects on magnetic moments and magnetocrystalline anisotropy in the Heusler phase Fe_2CoGa — •Georg Krugel, Wolfgang Körner, Daniel F. Urban und Christian Elsässer — Fraunhofer Institute for Mechanics of Materials IWM, Wöhlerstr. 11, 79108 Freiburg, Germany

In the search for new and cheap rare-earth-free hard-magnetic materials, Heusler phases are promising candidates. Depending on their chemical composition, high Curie temperatures and high magnetizations without rare earth elements can be achieved. By using a computational screening approach, Gillesen et al. [1] identified several Heusler phases with high magnetic moments like Fe_2CoGa or Fe_2CoAl.

However, in order to have a good hard-magnetic material with a defined easy axis a substantial intrinsic crystalline anisotropy is needed. Unfortunately, the Heusler phases with high magnetic moment generally crystallize in the regular or inverse cubic structure with zero anisotropy. Nevertheless, extended crystal defects like stacking faults or grain boundaries may lead to preferred crystal orientations and provide a way for optimizing the magnetic anisotropy through microstructure engineering.

We present a density functional theory study on extended defects in Fe_2CoGa which illustrates how much magnetocrystalline anisotropy can be achieved. Furthermore, the impact of the extended defects on the local magnetic moments and the total magnetization is analyzed.

[1] M. Gillessen and R. Dronskowski, J. Comput. Chem. 30, 1290 (2009)

MA 42.3 Thu 10:00 H34

Introducing magnetic functionality into oxide heterostructures by thermodynamic stabilization: $EuO/SrTiO_3$ — •Patrick Lömker[1], Timm Gerber[1], Andrei Gloskovskii[2], Wolfgang Drube[2], and Martina Müller[1,3] — [1]Forschungszentrum Jülich GmbH, PGI-6, Jülich, Germany — [2]DESY Photon Science, DESY, Hamburg, Germany — [3]Universität Duisburg-Essen, Duisburg, Germany

In order to introduce magnetic functionality into all-oxide heterostructures, we integrated ultra thin films of the ferromagnetic insulator EuO epitaxially on conducting 0.5% Nb doped $SrTiO_3(001)$ (Nb:STO).

We circumvented the use of thick buffer layers (e.g. SrO) to prevent over-oxidation of EuO films by making use of the thermodynamic properties of Eu metal to ultimately form EuO. In particular, *in situ* XPS shows that Eu-metal only deposition on Nb:STO leads to the formation of ultrathin stoichiometric EuO films through substrate supplied oxygen. Furthermore, the interplay between oxygen pressure, Eu flux and T_S is utilized to extended stoichiometric growth to larger film thicknesses. For $T_S = 20°C$ we report the formation of fully stoichiometric EuO films, whereas growth at elevated temperature (250-500°C) yields epitaxial integration with sub-ML interfacial Eu_2O_3.

Further analysis by LEED, RHEED and XRD reveals the epitaxial relationship EuO(110)/Nb:STO(100). *Ex situ* magnetic analysis shows bulk-like properties for optimized EuO ultra thin films. Finally, HAXPES experiments were performed at PETRA III confirming the thermodynamical stabilization of ferromagnetic EuO on Nb:STO.

MA 42.4 Thu 10:15 H34

Exchange Bias-Like Effect of an Uncompensated Antiferromagnet — •Bastian Henne, Verena Ney, Mariano de Souza, and Andreas Ney — Johannes Kepler Universität Linz - Austria

Commonly, exchange biasing is evidenced by a field-like *horizontal* shift of the $M(H)$-loop dominated by the FM [1]. In contrast, its microscopic origin is attributed to uncompensated spins, *i.e.*, an excess magnetization, of the antiferromagnet (AFM) exchange coupled to the FM [2]. This infers the presence of an additional *vertical* shift . Experimental observations of this shift are limited to few layered FM/AFM systems (for example [3]) and observations in the absence of a FM are lacking. In this contribution we present antiferromagnetic Co:ZnO as model system in which the uncompensated spins indeed exclusively lead to a vertical shift which is measurable by conventional magnetometry. Our findings pave the way for the exploration of the vertical exchange bias effect in the absence of a FM and the possibility to achieve a finite field-resistant magnetization in an uncompensated AFM.

[1] Nogúes, J. and Schuller, I.K., J. Magn. Magn. Mater. **192**, 203 (1999).
[2] Ohldag, H. *et al.*, Phys. Rev. Lett. **91**, 017203 (2003).
[3] Rana, R. *et al.*, Sci. Rep. **4**, 4138 (2014).

MA 42.5 Thu 10:30 H34

Magnetic properties of Fe doped spinel $CoCr_2O_4$ studied from first principles theory — •Biplab Sanyal, Shreemoyee Ganguly, and Raghuveer Chimata — Department of Physics and Astronomy, Uppsala University, Box-516, 75120 Uppsala, Sweden

We present a systematic study of the effects of Fe doping on the electronic and magnetic structures of spinel $CoCr_2O_4$ by ab initio density functional theory and Monte Carlo simulations. Our calculated magnetic structure for pristine $CoCr_2O_4$ correctly reproduces the experimental one with a q-vector of (0.67, 0.67,0.0). We show that the noncollinear spin structure with a non-zero q-vector in the spinel structure is driven towards collinearity by Fe doping by a complex interplay between interatomic exchange interactions. In the inverse spinel structure with 100 % Fe doping, a collinear antiferromagnetic order develops along with a half metallic electronic structure, which evolves due to the chemical disorder between Fe and Co in the B sites described by the coherent potential approximation. To the best of our knowledge, this is the first comprehensive theoretical study to understand the evolution of magnetic and electronic properties of multiferroic $CoCr_2O_4$ doped with Fe.

15 min. break

MA 42.6 Thu 11:00 H34

Thermodynamic Stability and Control of Oxygen Reactivity at Magnetic Oxide Interfaces: EuO on ITO — •Timm Gerber[1], Patrick Lömker[1], Bernardus Zijlstra[1], Claire Besson[2], David Müller[1], Willi Zander[3], Jürgen Schubert[3], Mihaela Gorgoi[4], and Martina Müller[1,5] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, Jülich, Germany — [2]Institut für Anorganische Chemie, RWTH Aachen University, Germany — [3]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, Jülich, Germany — [4]Helmholtz-Zentrum für Materalien und Energie GmbH, Berlin, Germany — [5]Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

As a prototypical all-oxide heterostructure, the ferromagnetic insulator europium monoxide (EuO) is synthesized on transparent and conductive indium tin oxide (ITO) virtual substrates. Non-destructive hard X-ray photoelectron spectroscopy (HAXPES) is employed to depth profile the chemical composition of the magnetic layer and the buried oxide-oxide interface. We find that the otherwise well-established adsorption-controlled EuO growth mode is not applicable here due to thermally activated oxygen diffusion from ITO. We present how to control the oxygen reactivity at the interface and discuss its origin in a thermodynamic analysis. Our complementary methodical strategy allows for a significant improvement of ultrathin EuO films with sizeable magnetic properties. Generally, our approach derives guidelines for the proper choice of oxide substrates and buffer layer materials for functional all-oxide heterostructures.

MA 42.7 Thu 11:15 H34

Ti_2MnZ (Z=Al, Ga, In) compounds: Nearly spin gapless Semiconductors — •Hongying Jia[1,2], Xuefang Dai[2], and Guodong Liu[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]School of Material Sciences and Engineering, Hebei University of Technology, Tianjin 300130, P. R. China

Spin gapless semiconductors with-low spin magnetic moments are promising functional materials due to their fascinating potential for realistic applications. The ideal spin gapless semiconductors exhibit zero magnetic moment and low external magnetic fields, leading to smaller energy losses. However, spin gapless semiconductors with zero magnetic moments are rarely reported up to now. Therefore, it is necessary to clarify the differences in the origin of the band gap in two spin channels for spin gapless magnetic semiconductors with Heusler structure. In our work [1], the electronic, structural and magnetic properties of Ti_2MnZ (Z=Al, Ga, In) compounds were systematically investigated using first-principles calculations. Our results demonstrate that these compounds are nearly spin gapless semiconductors and have a zero magnetic moment. The origin of the band gap in different spin directions will be discussed in detail. Besides, the effects of the lattice parameter and doping effects of the congeners on the width of the band gaps are demonstrated. These results will help to better understand the mechanism of spin gapless semiconductors and therefore promote the design of new spin gapless semiconductors.

[1] H. Y. Jia *et al.*, AIP Advances **4**, 047113 (2014)

MA 42.8 Thu 11:30 H34

Contributions from conduction electrons and localized moments to the magnetization in Cu_2MnAl as separated by spin polarized measurements — •Josef Andreas Weber[1], Andreas Bauer[1], Peter Böni[1], Hubert Ceeh[1], Stephen Dugdale[2], Atsuo Kawasuso[4], Michael Leitner[3], Christian Pfleiderer[1], and Christoph Hugenschmidt[1,3] — [1]Physik-Department, Technische Universität München, James-Franck Straße, 85748 Garching, Germany — [2]H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstraße 1, 85748 Garching, Germany — [4]Advanced Science Research Center, Japan Atomic Energy Agency, 1233 Watanuki, Takasaki, Gunma 370-1292, Japan

The distinction between localized and itinerant ferromagnetism is for some systems still a contentious issue. In Mn based Heusler systems it is usually assumed, that all the magnetic moments are localized at the Mn atoms. However it was shown, that in Cu_2MnAl there exist different Fermi surfaces for the majority and minority spin channel and therefore also the conduction electrons contribute substantially to the the total magnetic moment [1]. Here we report our results obtained by comparing spin polarized 2D-ACAR measurements with recent magnetic Compton scattering measurements and with spin polarized positron lifetime experiments.

[1] J. A. Weber et al., Phys. Rev. Lett. **115** 206404 (2015).

MA 42.9 Thu 11:45 H34

Chemical disorder as engineering tool for magnetic properties and spin-polarization in Mn3Ga-based Heusler systems — •Lukas Wollmann, Stanislav Chadov, Sunil Wilfred D'Souza, Gerhard H. Fecher, and Claudia Felser — Max-Planck-Insitute for Chemical Physics of Solids

The present contribution discusses the effect of random substitution of Mn in Mn_3Ga as a constructive disorder phenomenon, which, for instance, allows to chemically control the spin-polarization of the charge carriers. It is based on *spin-selective electron localization* encountered by the first-principles calculations on the family of tetragonal Mn-based Heusler materials $Mn_{3-x}Y_xGa$ [1,2]. Our calculations indicate that *spin-selective localization* can be introduced by substituting Mn with almost any 3d transition metal element (Sc, Ti, V, Cr, Fe, Co, Ni, Cu) as well as with several heavier species as Os, Ir or Pt. The spin-polarization was derived from the spin-projected residual conductivity tensor computed within the Kubo-Greenwood formalism within the SPR-KKR method [3], which properly accounts for the effects of electron localization induced by the scattering due to chemical disorder. In this way one might obtain the series of highly spin-polarized alloys with noticeable magnetocrystalline anisotropy, combining the advantages of tetragonal and cubic Heusler compounds.

[1] S. Chadov *et al.*, Phys. Rev. B **91** 094203 (2015); [2] L. Wollmann *et al.*, J. Phys. D: Appl. Phys. **48** 164004 (2015); [3] H. Ebert *et al.*, Rep. Prog. Phys. **74** 096501 (2011).

MA 42.10 Thu 12:00 H34

Yttrium Iron Garnet Thin Films with Very Low Damping Obtained by Recrystallization of Amorphous Material — •Christoph Hauser[1], Tim Richter[1], Nico Homonnay[1], Christian Eisenschmidt[1], Hakan Deniz[2], Dietrich Hesse[2], Stefan Ebbinghaus[1], and Georg Schmidt[1] — [1]Martin-Luther University Halle-Wittenberg, Halle, 06120, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, 06120, Germany

Yttrium Iron Garnet is a room temperature ferrimagnet, which has recently gained importance for magnonics [1]. For the integration into magnonic devices, however very thin films must be used which are mostly fabricated by pulsed laser deposition (PLD) and often suffer from increased damping. Using room temperature deposition and subsequent annealing in an oxygen atmosphere much lower damping can be achieved. For a 56 nm thick layer a damping constant of $\alpha = 6.15 \cdot 10^{-5}$ and a linewidth as small as 1.30 Oe @9.6 GHz are obtained which are the lowest values for PLD grown thin films reported so far. Even for a 20 nm thick layer a damping constant of $\alpha = 7.39 \cdot 10^{-5}$ is found. In this case the FMR linewidth is 3.49 Oe @9.6GHz. The layers show high crystalline quality and sub nanometer surface roughness in various structural characterizations. Our results not only present a method of depositing thin film YIG of unprecedented quality but also open up new options for the fabrication of thin film complex oxides or even other crystalline materials. We are going to present the results of various experiments using different layer thicknesses and annealing parameters. [1]Chumak et al. Nat. Commun. 5, 4700 (2014).

MA 42.11 Thu 12:15 H34

Competing Superexchange Interactions in Sr2-xCaxCoOsO6 Double Perovskite Osmates — •Ryan Morrow[1,2], Rohan Mishra[1], Oscar D. Restrepo[1], Molly R. Ball[1], Wolfgang Windl[1], Sabine Wurmehl[2,3], Ulrike Stockert[2,3], Bernd Büchner[2,3], Jiaqiang Yan[4], Michael A. McGuire[4], John W. Freeland[5], Daniel Haskel[5], and Patrick M. Woodward[1] — [1]OSU, Columbus, OH, United States — [2]IFW, Dresden, Germany — [3]TUD, Dresden, Germany — [4]ORNL, Oak Ridge, TN, United States — [5]ANL, Argonne, IL, United States

Double perovskites containing mixed transition metal cations have exhibited numerous desirable properties such as colossal magnetoresistance, half metallic transport, and high temperature ferrimagnetism. However, a predictive understanding of the superexchange mechanisms which control the magnetism of these materials when they are insulating and contained ordered 3d and 4d or 5d transition metals has remained elusive. In this work, the novel insulators Sr2CoOsO6, SrCaCoOsO6, and Ca2CoOsO6 are studied through a combination of AC and DC magnetometry, specific heat, X-ray magnetic circular dichroism, and neutron powder diffraction in order to characterize two antiferromagnetic orders in Sr2CoOsO6, two spin glass transitions in SrCaCoOsO6, and ferrimagnetic ordering in Ca2CoOsO6. The details of the crystal structures will be used to draw connections between the tuning of bonding geometry through chemical pressure and the competition between short and long range superexchange interactions on the resulting magnetic ground states.

MA 43: Transport: Molecular Electronics and Photonics 2 (Joint session of CPP, DS, HL, MA, O and TT organized by TT)

Time: Thursday 15:00–16:00 Location: H23

MA 43.1 Thu 15:00 H23

First-principles calculation of the thermoelectric figure of merit for [2,2]paracyclophane-based single-molecule junctions — •Marius Buerkle[1], Fabian Pauly[2], and Yoshihiro Asai[1] — [1]AIST Tsukuba — [2]University Konstanz

Here we present a theoretical study of the thermoelectric transport through [2,2]paracyclophane-based single-molecule junctions [1]. Combining electronic and vibrational structures, obtained from density functional theory (DFT), with nonequilibrium Green's function techniques allows us to treat both electronic and phononic transport properties at a first-principles level. Paracyclophane derivatives offer a great flexibility in tuning their chemical properties by attaching different functional groups. We show that, for the specific molecule, the functional groups mainly influence the thermopower, allowing us to tune its sign and absolute value. We predict that the functionalization of the bare paracyclophane leads to a largely enhanced electronic contribution ZelT to the figure of merit. Nevertheless, the high phononic contribution to the thermal conductance strongly suppresses ZT. Our work demonstrates the importance to include the phonon thermal conductance for any realistic estimate of the ZT for off-resonant molecular transport junctions.

[1] M. Buerkle et al., PRB **91**, 165419 (2015)

MA 43.2 Thu 15:15 H23

Switching the conductance of a molecular junction by proton transfer — •Dominik Weckbecker, Pedro B. Coto, Chriszandro Hofmeister, and Michael Thoss — Institut für Theoretische Physik, Staudtstraße 7/B2, 91058 Erlangen, Germany

The idea of designing switches or diodes using single molecules has motivated intensive experimental and theoretical research on the conductance properties of these systems. In particular, it has been demonstrated that a molecular junction may be used as a nanoswitch if the molecular bridge has two stable states with different conductance that can be reversibly transformed into each other [1]. In this contribution, we explore the possibility of switching a molecular junction using a proton transfer reaction triggered by an external electrostatic field [2]. The study uses transport theory based on first-principles electronic structure calculations [2,3] and considers molecular junctions with graphene or gold as material for electrodes. We show that for the systems investigated, proton transfer can be used for the reversible interconversion between two states, which exhibit different degrees of delocalization of the π-electrons and therefore very different conductance.

[1] S. J. van der Molen et al., J. Phys.: Cond. Mat. **22**, 133001 (2010)
[2] C. Hofmeister et al., J. Mol. Model. **20**, 2163 (2014)
[3] M. Brandbyge et al., PRB **65**, 165401 (2002)

MA 43.3 Thu 15:30 H23

Design rules for molecular electronics: Diarylethene molecules und derivatives — •Lokamani Lokamani[1], Torsten Sendler[1], Peter Zahn[1], Sibylle Gemming[1,2], and Artur Erbe[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01314 Dresden, Germany. — [2]Instiute of Physics, Technische Universität, 09107 Chemnitz, Germany.

Diarylethenes, a class of photosensitive molecules which exhibit photochoromism, can be switched between open- and closed-ring isomers. In break-junction experiments diarylethene derivatives[1] in open and closed-ring forms can be distinguished by a low and high conductance state respectively with a difference in current levels of about one order of magnitude. In addition, these molecules exhibit stable electrical characteristics in both conductance states. Here, we study the electronic transport properties of such derivatives at the level of single molecules. In particular, we analyze the effect of various electron accepting and donating groups on the conductance properties of single molecules attached to gold electrodes. We explore the underlying design rules for molecular electronics comparing break-junction experi-

ments and the theoretical investigations on diarylethene molecules and derivatives.
[1] T. Sendler et al., Advanced Science **2**, 1500017 (2015)

MA 43.4 Thu 15:45 H23

Experimental investigation of the role of electron-phonon-coupling on the Mott critical behavior in the organic charge-transfer salts κ-(BEDT-TTF)$_2$X — •E. Gati[1], M. Garst[2], R.S. Manna[1], U. Tutsch[1], B. Wolf[1], S. Hartmann[1], L. Bartosch[3], T. Sasaki[4], H. Schubert[1], J.A. Schlueter[5], and M. Lang[1] — [1]Physikalisches Inst., Goethe Uni, SFB/TR49, Frankfurt, DE — [2]Inst. f. Theo. Physik, Universität zu Köln, DE — [3]Inst. f. Theo. Physik, Goethe Uni, FfM, DE — [4]IMR, Tohoku University, Sendai, Japan — [5]Materials Science Division, Argonne National Laboratory, USA

The Mott transition is one of the key phenomena of strongly correlated electron systems. Of fundamental interest is the determination of its critical behavior and the underlying universality class. Despite intensive experimental efforts, the universality class is still unresolved. A key aspect, which has not been addressed in these approaches, is the role of electron-phonon-coupling as it is supposed to alter the critical properties to Landau criticality [1]. We will present thermal expansion studies under pressure [2] on the organic charger-transfer salt κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl. This technique is a very sensitive tool to detect critical behavior [3] as well as influences of the lattice on the electronic subsystem [1]. Our results clearly show a breakdown of Hooke's law of elasticity which is a direct evidence for significant electron-phonon-coupling. Furthermore, we will discuss its effect on the critical exponents determined by this thermodynamic probe.
[1] Zacharias et al., PRL **109**, 176401 (12)
[2] Manna et al., Rev. Sci. Instrum. **83**, 085111 (2012)
[3] de Souza et al., PRL **99**, 0370031 (2007)

MA 44: Spininjection / Spin currents in heterostructures

Time: Thursday 15:00–18:00 Location: H31

MA 44.1 Thu 15:00 H31

room temperature spin transport in n-type Ge — •Masashi Shiraishi[1], Sergey Dushenko[1,2], Yuichiro Ando[1], Teruya Shinjo[1], and Maksym Myronov[3] — [1]Kyoto University, Japan — [2]Osaka University, Japan — [3]Univ. Warwick, UK

After the success of room temperature (RT) spin transport in Si [1,2] and RT operation of spin MOSFET using Si [3,4], the next milestone in semiconductor spintronics was set to realization of RT spin transport in Ge because carrier mobility of Ge is larger than that in Si. Much effort has been dedicated for the realization, the temperature range of the spin transport in Ge was limited below 225 K when an electrical method was used [5,6]. We introduced the other potential method for spin injection and transport in semiconductor, i.e., dynamical spin pumping. In this presentation, we report on RT spin transport in n-type Ge, where spin diffusion length is estimated to be ca. 600 nm [7]. Temperature dependence of the spin diffusion length tells us that the spin relaxation is induced by impurity scattering. The detail is discussed in the presentation.

[1] T. Suzuki, M. Shiraishi et al., Appl. Phys. Express 4, 023003 (2011). [2] E. Shikoh, M. Shiraishi et al., Phys. Rev. Lett. 110, 127201 (2013). [3] T. Sasaki, M. Shiraishi et al., Phys. Rev. Applied 2, 034005 (2014). [4] T. Tahara, M. Shiraishi et al., Appl. Phys. Express 8, 113004 (2015). [5] Y. Zhou et al., Phys. Rev. B84, 125323 (2011). [6] K. Kasahara et al., Appl. Phys. Express 7, 033002 (2014). [7] S. Dushenko, M. Shiraishi et al., Phys. Rev. Lett. 114, 196602 (2015).

MA 44.2 Thu 15:15 H31

Charge neutral tunneling spectroscopy using spin Hall effect — •Wei Chen and Manfred Sigrist — ETH Zurich, Switzerland

When charge current passes through a normal metal that exhibits spin Hall effect, spin accumulates at the edge of the sample in the transverse direction. We predict that the accumulated spin can quantum tunnel through an insulator or vacuum to reach a metallic or insulating magnet without transferring charge, realizing the spintronic analog of field emission. This quantum tunneling of spin causes a spin-transfer torque, and implies a new type of charge neutral tunneling spectroscopy that can probe the magnetic excitation of a bulk insulator or a metallic thin film in a noninvasive manner. [1] W. Chen, M. Sigrist, J. Sinova, and D. Manske, Phys. Rev. Lett. 115, 217203 (2015).

MA 44.3 Thu 15:30 H31

Electrical Spin Injection into an Inverted 2DEG Structure — •Martin Buchner, Thomas Kuczmik, Martin Oltscher, Mariusz Ciorga, Josef Loher, Dieter Schuh, Tobias Korn, Christian Schüller, Dominique Bougeard, Dieter Weiss, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

In 1990 Datta and Das proposed a novel transistor concept, which utilizes the electron's spin as a new degree of freedom [1]. The current modulation arises from spin precession, which originates from the Bychkov-Rashba-term of spin-orbit-interaction. One key ingredient for the experimental realization of the device is spin injection into a two-dimensional electron gas (2DEG), which turned out to be a challenging task.

In this study, we demonstrate spin injection into a high mobility 2DEG, investigated by means of scanning Kerr microscopy at the cleaved edge of the sample. In detail, we investigate samples with the 2DEG confined at an (Al,Ga)As/GaAs interface; ferromagnetic (Ga,Mn)As contacts are used as spin aligners. Former investigations on these structures have shown a strong enhancement of the nonlocal voltage signal for certain bias conditions [2]. We probe the spatial distribution of the spins with the aid of a diode laser directly underneath the injecting contact. Hanle depolarization gives a measure for the spin lifetimes.

[1] S. Datta, B. Das, Appl. Phys. Lett. 56, 665 (1990).
[2] M. Oltscher et al., Phys. Rev. Lett. 113, 236602 (2014).

MA 44.4 Thu 15:45 H31

Skew-scattering Anomalous and Spin Hall effects in L1$_0$-**ordered FePt alloys** — •Bernd Zimmermann, Nguyen H. Long, Phivos Mavropoulos, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The Spin Hall effect (SHE) and inverse SHE are of fundamental importance for spinorbitronics, as they are the main source of spin current generation and detection. Intimately related is the anomalous Hall effect (AHE), which in addition appears in magnetic materials. New insights into the common underlying mechanisms can be anticipated from a combined study of both. Here, we turn our attention to the L1$_0$-ordered FePt alloy and determine by *ab-initio* calculations the disorder-induced skew-scattering contribution to AHE and SHE. We investigate the role of different antisite-defects, such as Pt atoms occupying Fe sites (and vice versa) where the stoichiometry deviates from the 1:1 ratio, or where the ideal stoichiometry remains but nearest-neighbor Fe and Pt atoms switch sites and form a dimer. Our results reveal that Fe-antisite defects show the largest Hall angles of about 1%, which is of the same order of magnitude as experimentally measured Hall angles [1]. On the contrary, Hall angles for Pt-antisite defects are smaller in magnitude and of different sign. As we show, the effect of FePt-dimers can only be addressed by explicit *ab-initio* calculations, while the approximative Matthiessen rule greatly fails.

[1] K.M. Seemann *et al.*, Phys. Rev. Lett. **104**, 076402 (2010).

MA 44.5 Thu 16:00 H31

Spin-Hall magnetoresistance and spin Seebeck effect in non-collinear magnetic insulators — •Aisha Aqeel[1], Nynke Vlietstra[1], Jeroen A. Heuver[1], Gerrit E. W. Bauer[2,3], Beatriz Noheda[1], Bart J. van Wees[1], and Thomas T. M. Palstra[1] — [1]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands — [2]Institute for Materials Research and WPI-AIMR, Tohoku University, Sendai, Miyagi 980-8577, Japan — [3]Kavli Institute of NanoScience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Recently, the spin-Hall Magnetoresistance (SMR) and the spin Seebeck effect (SSE) have attracted much interest in the field of spintronics.

However, these effects have been studied only for collinear magnetic systems. The nature and sensitivity of these effects in non-collinear magnetic insulators is still unknown. Here, we present a study of the SMR and the SSE in a non-collinear magnetic insulator $CoCr_2O_4$ (CCO) with Pt contacts. $CoCr_2O_4$ (CCO) is a spinel with a collinear ferrimagnetic state below $T_c = 94$ K and non-collinear magnetic phases at lower temperatures. Through lock-in detection technique, we show the existence of the SMR and the SSE in different magnetic phases. We observe a large enhancement in SMR and SSE in the non-collinear phase of the CCO, which indicates that the interaction between spins at the Pt|CCO interface is more efficient in the non-collinear magnetic state. Our results show that the spin transport at the Pt|CCO interface is sensitive to different magnetic phases but cannot be explained solely by the bulk magnetization.

15 min. break

MA 44.6 Thu 16:30 H31

Spin-pumping and Inverse Spin-Hall-effect in Strontium ruthenate grown on Yttrium Iron garnet — •Tim Richter[1], Maximilian Paleschke[1], Martin Wahler[1], Frank Heyroth[2], Hakan Deniz[3], Dietrich Hesse[3], and Georg Schmidt[1,2] — [1]Fachbereich Physik, Martin-Luther-Universität Halle Wittenberg, Halle(Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Halle(Saale), Germany — [3]Max-Planck-Institut für Mikrostrukturphyik, Halle(Saale), Germany

Ferromagnetic oxides recently gained importance due to their application in spintronics. They can exhibit an extraordinary high spin polarization, which can be used for highly efficient tunneling magnetoresistance but also for spin pumping and inverse spin Hall effect invastigations. Especially $Y_3Fe_5O_{12}$ (YIG - ferrimagnetic oxide at room temperature) is a prototypical source for spin pumping because its insulating nature and exceptionally low damping greatly facilitate the experiments. YIG is used for many investigation of ISHE using metals or polymers as a spin sink. Here we show an all-oxide heterostructure consisting YIG as a source and $SrRuO_3$ as a spin sink. Both materials were grown in situ with PLD. Although YIG is grown in a garnet structure and SRO naturally in a perovskite structure, we observe spin-pumping in SRO by FMR-measurements. Even the ISHE in SRO can be detected. We will present results from structural characterization including TEM and electron diffraction as well as from FMR and ISHE measurements. These results open up new possibilities for all oxide heterostructures with different crystal systems in spintronics.

MA 44.7 Thu 16:45 H31

Switchable spin-current in a non-magnetic-metal/ferroelectric tunnel junction — Andrea Neroni, Daniel Wortmann, Stefan Blügel, and •Marjana Ležaić — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The Rashba effect produces a crystal-momentum dependent spin-splitting of the electronic bands. As a consequence of the inversion symmetry breaking, it is often observed at the surfaces, due to the potential gradient in the direction normal to the surface. In bulk, the splitting is present in some structures with the appropriate symmetry breaking. For example, it was shown [1, 2] that the effect could be observed in ferroelectrics containing heavy elements (such as GeTe).

Using Density Functional Theory calculations, we study a tunnel junction consisting of non-magnetic metallic leads and GeTe as the barrier material. We show that the Rashba-like splitting of the GeTe bands causes a momentum and spin-dependence of the electron-current tunneling probabilities and propose a device which exploits this dependence to obtain a switchable spin-current that can be controlled by the polarization direction of the ferroelectric barrier [3].

We acknowledge the support by Helmholtz Young Investigators Group Programme VH-NG-409.

[1] D. Di Sante et al., Adv. Mater. **25**, 509 (2013). [2] M. Liebmann et al., Adv. Mater. DOI: 10.1002/adma.201503459 (2015) [3] A. Neroni, PhD Thesis, RWTH Aachen

MA 44.8 Thu 17:00 H31

Boltzmann-equation model for spin-dependent transport on ultrashort timescales — •Dennis Michael Nenno and Hans Christian Schneider — Physics Department and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern

Spin-polarized currents have been shown to play an important role in ultrafast demagnetization [1,2,3].

We use a spin-resolved Boltzmann equation to simulate charge and spin dynamics in an iron/gold hetero-structure. The excitation conditions are modeled after the ultrashort laser excitation as in Ref. [1].

The dynamical equation is solved using numerical methods originally applied in plasma physics in a reduced phase space in order to limit the computational cost. Scattering effects are included at the level of the relaxation time approximation. This calculation accounts for microscopic effects such as a k-dependent excitation and deviations from the equilibrium distribution. We study the influence of different excitation spectra injected from the ferromagnetic iron layer into the adjacent nonmagnetic gold slab and their influence on the resulting spin and charge dynamics. In additon, we compare the results with the macroscopic wave-diffusion equations for spin and charge transport [3].

[1] A. Melnikov *et al.*, Phys. Rev. Lett. 107, 076601 (2011).
[2] M. Battiato, K. Carva, and P. M. Oppeneer, Phys. Rev. B 86, 024404 (2012).
[3] S. Kaltenborn, Y. H. Zhu, and H. .C. Schneider, Phys. Rev. B 85, 235101 (2012)

MA 44.9 Thu 17:15 H31

Skyrmions and defects: from pinning to new memory designs — •Jan Müller and Achim Rosch — Institut für Theoretische Physik, Universität zu Köln, Cologne, Germany

In the last few years, magnetic whirls with integer winding number, so-called 'skyrmions', have gained a lot of attention due to their thermal (topological) stability, nanometer scale size, and the ability to be controlled at ultra low current densities. These properties make skyrmions promising candidates for future logic devices and in particular magnetic memory devices. As the most prominent example, the skyrmion racetrack memory has been proposed.

Using numerical and analytical calculations, we investigated the interaction of a single skyrmion with different kinds of single defects. We will present the possible phases of interaction [1]. Finally we will motivate an alternative to the skyrmion racetrack, that is supposed to take care of most of its disadvantages and be a realistic candidate for skyrmion memory devices.

[1] J. Müller and A. Rosch, Phys. Rev. B 91, 054410

MA 44.10 Thu 17:30 H31

Investigation of the spin pumping effect in epitaxially grown Fe/MgO/Pt systems — •Mihalceanu L.[1], Keller S.[1], Conca A.[1], Pliatsikas N.[2], Karfaridis D.[2], Vourlias G.[2], Hillebrands B.[1], and Papaioannou E. Th.[1] — [1]TU Kaiserslautern, Erwin-Schrödinger-Straße 1, 67663 Kaiserslautern — [2]Dep. of Physics, Aristotle University of Thessaloniki, 54124 Thessaloniki, GR

Understanding and improving the generation of spin currents at the interface of thin ferromagnetic (FM)/ non magnetic (NM) and FM/ Insulator (I)/NM stacks provides a challenging opportunity for developing faster data-processing nanoelectronics devices with low energy consumption. Here we investigate the influence of an MgO tunneling barrier in Fe/MgO/Pt systems on the spin pumping effect which is based upon a spin current getting injected from the FM into the NM layer. The injected spin current is detected via the inverse spin Hall effect (ISHE). The signal is analysed by fitting a symmetric and an antisymmetric Lorenzian formula. By means of the spin pumping FMR measurements we demonstrate that an increasing thickness of the MgO interlayer leads to an increased signal of ISHE DC-voltage with a more pronounced dependence of the symmetric part over the antisymmetric one. We correlate our results with structural analysis of the trilayers. Employing X-ray diffraction we show single crystal growth of Pt on top of an MgO interlayer while Fe grows epitaxially on the MgO substrate. X-ray photoemission spectroscopy is also used to reveal the chemical synthesis of the interfaces. Financial support by the Carl Zeiss Stiftung and by the DAAD-PPP GR program are gratefully acknowledged.

MA 44.11 Thu 17:45 H31

Investigation of the unidirectional spin heat conveyer effect in a 200nm thin Yttrium Iron Garnet film — •Olga Wid[1], Jan Bauer[2], Otwin Breitenstein[2], and Georg Schmidt[1,3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle (Saale), Germany — [3]Interdisziplinäres Zentrum für Materialwissenschaften, MLU Halle-Wittenberg, Germany

In 2013 An et al. have shown that nonreciprocal spin waves, so-called Damon-Eshbach modes, can be used to transport heat. The direction of the heat flow is independent from thermal gradients and can be switched by reversing the applied magnetic field [1]. The measurements reported so far were performed with an infrared camera on YIG films with thicknesses of few micrometers to hundreds of micrometers. We are able to demonstrate the unidirectional spin heat conveyer effect even on a 200nm thin YIG film, using Lock-in thermography [2]. In our measurements we can discern temperature differences smaller than 1 mK. These results are important for measurement of the inverse spin-hall effect (ISHE) and spin caloritronics, showing that small temperature differences can be created even in thin layers when Damon-Eshbach modes are involved. These can easily lead to thermovoltages with exactly the same signature as the ISHE voltage which also reverses sign with the magnetic field [3]. [1] T. An et al., Nat Mater 12, 549 (2013) [2] O. Breitenstein, M. Langenkamp, "Lock-in Thermography: Basics and Use for Functional Diagnostics of Electronic Components", Springer (2003) [3] Z. Qiu, AIP Advances 5, 057167 (2015)

MA 45: Focus: Disorder Engineering as a Tool for Material Science

Organized by S. Chadov (MPI-CPfS Dresden) and J. Minar (LMU München, ZCU Pilsen)

A large number of the material science tasks can be reduced to a rather generic formulation: how to increase an intensity of the useful properties ('signal') or how to reduce the unwanted ones ('noise')? The diversity of the degrees of freedom in polyatomic systems makes such 'signal-to-noise' control rather sophisticated and expensive. In modern technologies, operating on the nanoscale, the requirements for basic elements are often quite stringent: high crystalline order, precise target compositions, etc. Alternative improvements can be provided by disorder. In this context, a desired improvement can be achieved by introducing a specific disorder, suppressing 'noise' intensity, but preserving the intensity of 'signal'. Such engineering requires establishing of the relationships between the 'useful' characteristics, materials structure and particular disorder. Here we would like to assist for a systematic view on alternative adjustment of materials functionalities via manipulating internal degrees of freedom, provided by disorder. We give an overview of various types of disorder and their specifics, methods dealing with disorder explicitly and examples demonstrating the efficiency of such engineering.

Time: Thursday 15:00–17:15 Location: H32

Invited Talk MA 45.1 Thu 15:00 H32
Charge carrier scattering and electronic transport in graphene — •Mikhail Katsnelson — Radboud University, Nijmegen, Netherlands

High electron mobility in graphene is one of its most interesting properties for potential applications. Despite intensive efforts, both experimental and theoretical, we still have no complete understanding of main electron scattering mechanisms and main limiting factors restricting the mobility. It is clear that a long-range scattering is important since short-range scatterers with radius of potential smaller than the electron wavelength are irrelevant for massless Dirac fermions. Three most probable candidates are charge impurities, scattering by elastic deformations created by frozen ripples and other defects, and resonant scattering centers (the last case also deals with long-range effects due to divergence of the scattering length). I review a theory of these mechanisms, together with relevant experimental results and first-principle calculations. I discuss also peculiarities of electron transport in bilayer graphene and temperature dependence of resistivity for freely suspended graphene samples. In the latter case, two-phonon processes involving bending mode give probably the main contribution. I will consider also theory of minimal conductivity in graphene and discuss the role of electron-electron interactions. Electronic transport in graphene on boron nitride and the role of moire pattern formed in this case will be also reviewed.

Invited Talk MA 45.2 Thu 15:30 H32
Electrons in disordered systems: extensions to the coherent potential approximation for short- and long-ranged order effects — •Julie Staunton[1], Alberto Marmodoro[2], and Arthur Ernst[2] — [1]University of Warwick, Coventry CV4 7AL, United Kingdom — [2]Max-Planck-Institut fur Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

The extension of the coherent potential approximation (CPA), namely the Korringa-Kohn-Rostoker (KKR)-nonlocal-CPA method, describes short- and partial long-range order effects on the electronic structure of disordered materials and has been incorporated into a full electronic density functional theory (DFT) and electronic transport formalism. Here we briefly review this method and show how it can be combined with a simple treatment of the statistical mechanics of slowly varying degrees of freedom so that, in principle, an ab-initio theory of phase transitions can be achieved along with descriptions of the development of both short- and long-range order. In this context we use the DFT-based 'disordered local moment' (DLM) picture for magnetism where slowly fluctuating local moments on atomic sites can emerge from the interacting electrons of many materials. Whilst this picture works well for many rare earth and transition metal magnets, fluctuating moments do not establish naturally over such small regions for some materials. We show how the DFT-DLM theory can be extended to these materials with the use of the KKR-NLCPA to allow for more extensive, slow magnetic fluctuations and revisit the description of the paramagnetic states of iron, cobalt and nickel.

15 min. break

Invited Talk MA 45.3 Thu 16:15 H32
Percolation and other models for quenched disorder in materials, and some consequences of this disorder on physical properties. — •Kurt Binder — Inst. of Physics, JGU Mainz

An introductory review of percolation phenomena in solids is given, starting out with the example of diluted ferromagnets, where the spontaneous magnetization vanishes at the percolation threshold already in the ground state. Extensions such as correlated percolation will be mentioned, from clusters in the Ising model to percolation of nanorods in the continuum, emphasizing to understand electrical conductivity. In sodium silicate glasses both the rigid silica network and a network of sodium-rich channels percolate simultaneously, and this feature explains the strong ionic conductivity of these materials.

Invited Talk MA 45.4 Thu 16:45 H32
The Impact of Disorder on Transport in crystalline Phase Change Materials — •Matthias Wuttig — RWTH Aachen

Understanding charge transport in phase change materials (PCM) is crucial to extend the application range of these exciting materials. Hence, we have studied the resistivity of crystalline phase change materials. A pronounced dependence of the room temperature resistivity upon annealing temperature is observed for crystalline PCMs such as Ge1Sb2Te4. This finding is corroborated by low temperature measurements as well as FTIR data, which confirm that a metal * insulator transition is observed without a change in crystallographic state. This is indicative for an electronically driven MIT [1].

Such an MIT can be achieved if the electron correlation exceeds a critical value (Mott MIT). A second route to insulating behavior has been attributed to increasing disorder, which turns a metal into an insulator with localized states. Arguments for disorder induced localization of charge carriers will be presented, which reveal that vacancy ordering drives the MIT [2]. The potential of disorder for applications as well as our fundamental understanding of solids is discussed. [1] T. Siegrist et al., Nature Materials 10, 202, (2011) [2] W. Zhang et al., Nature Materials, 11, 952 (2012).

MA 46: Magnetic Measurement Methods

Time: Thursday 15:00–18:30 Location: H33

Invited Talk MA 46.1 Thu 15:00 H33

Advanced magneto-optical microscopy: Magnetoelectric sensors, spin-waves, and beyond — •Jeffrey McCord[1], Necdet Onur Urs[1], Mikhail Kustov[1], Babak Mozooni[1], Cai Müller[1], Matic Klug[1], Volker Röbisch[2], Patrick Hayes[2], Dirk Meyners[2], Eckhard Quandt[2], Roland Mattheis[3], Robin John[4], and Markus Münzenberg[4] — [1]Nanoscale Magnetic Materials - Magnetic Domains, Institute for Materials Science, Kiel University, Kiel, Germany — [2]Inorganic Functional Materials, Institute for Materials Science, Kiel University, Kiel, Germany — [3]IPHT Jena, Jena, Germany — [4]Ernst.Moritz-Arndt Universität Greifswald

Recent developments of the observation of magnetic domains and domain walls by wide-field optical microscopy based on the magneto-optical Kerr, Faraday, and Voigt effect are reviewed. Special emphasis is given to the imaging using higher order magneto-optical effects. Fundamental concepts and advances in methodology are discussed that allow for imaging of magnetic domain formation on a wide span of length and time scales, including time-resolved imaging of spin-wave propagation and electric field induced domain wall rotation, and optical induced magnetization reversal. Magneto-optical multi-effect domain imaging techniques are presented. Beyond domain imaging, the use of magneto-optical techniques for local temperature sensing is demonstrated.

15 min. break

MA 46.2 Thu 15:45 H33

Incorporating Nanosecond Time Resolution into Scanning Electron Microscopy with Polarization Analysis — •Fabian Kloodt, Robert Frömter, Susanne Kuhrau, Philipp Staeck, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

The Scanning Electron Microscope with Polarization Analysis (SEMPA) is well established to investigate the magnetic microstructure at surfaces and in ultrathin films. Up to now only stationary measurements over several minutes of acquisition time were feasible. Our instrument is using a LEED-based spin-polarization analyzer, where the intensity of four LEED beams is monitored via single-electron counting and analyzed to calculate the magnetic contrast. Making use of modern fast electronics, the arrival time of each single electron can be determined. In this way the obtained magnetic information can be split up into distinct time slices with respect to the phase of an external periodic voltage that drives the magnetization dynamics at the sample. Results of field-driven excitations of 60nm thick FeCoSiB rectangles in the diamond state as well as squares in the Landau state will be shown and the dynamics of coupled and uncoupled vortex gyration is extracted. A temporal resolution of 700ps is achieved. The present state of the method, limitations and the development potential will be discussed.

MA 46.3 Thu 16:00 H33

Magnetization and Spin Sensitive Real and Momentum Space Imaging in Laser-based Photoemission — •Maximilian Staab[1,2], Dima Kutnyakhov[1], Robert Wallauer[1], Hans Joachim Elmers[1,2], Mathias Kläui[1,2], and Gerd Schönhense[1,2] — [1]Johannes Gutenberg-Universität Mainz — [2]Graduate School Materials Science in Mainz

On the quest to faster magnetic imaging we exploit the magnetic circular dichroism in threshold photoemission (TPMCD) in the excitation by a laboratory-based Ti-sapphire laser, providing circularly polarized light of 1.6 eV and 3.2 eV. The corresponding asymmetries are based on different probabilities of transitions between spin-dependent electronic bands in the near photoemission threshold region. We show spatially resolved PEEM images of the magnetic domain pattern of epitaxially grown ultrathin Co/Pt(111) films. By utilizing time-of-flight momentum microscopy we investigate the electronic transitions that are responsible for the TPMCD effect. The time-of-flight momentum microscope allows for an efficient acquisition of angular-resolved photoemission spectra [1]. Additionally, we perform spin-resolved measurements with this method by reflecting the imaging electron beam at an Ir(001) spin filter crystal. While maintaining the band structure pattern they show an overall high spin asymmetry with a pronounced maximum in a flat band slightly below the Fermi level. The spin polarization and the magnetic circular dichroism are compared with theoretical calculations [2]. [1]G. Schönhense, K. Medjanik, H.-J. Elmers, JESRP, 200, 84-118,(2015) [2]K. Hild et al., Phys. Rev. B 82, 195430,(2010)

MA 46.4 Thu 16:15 H33

Study of Magnetic Vortex Oscillations in Permalloy Disks by Lorentz TEM and Differential Phase Contrast Microscopy — •Johannes Wild, Michael Vogel, Michael Mueller, Christian Back, and Josef Zweck — Institute of Experimental and Applied Physics, University of Regensburg

In a cylindrical nanodisk with a thickness of a few ten nanometers the magnetic ground state is a vortex. The magnetization curls in the plane of the disk either in clockwise or counterclockwise circulation and points out of the plane at the center. The center is called vortex core and there the magnetization can point either up or down.

We structured Permalloy ($Ni_{80}Fe_{20}$) disks on SiN_3 membranes and investigated them in the transmission electron microscope (TEM) while applying an AC spin-polarized current. The quantitative in-plane induction of the disks is imaged in Lorentz TEM mode and with differential phase contrast microscopy (DPC). To our knowledge we show the first DPC measurements of oscillating vortices.

We investigated the behavior of the vortex core oscillation on the applied frequencies and the temperature dependence of the resonance frequency.

MA 46.5 Thu 16:30 H33

Magnetic force microscopy sensors based on nanowire mechanical resonators — •Thomas Mühl[1], Christopher F. Reiche[1], Julia Körner[1], Clemens Gütter[1], and Bernd Büchner[1,2] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

Magnetic force microscopy (MFM) employing monopole-type probes allows for quantitative measurements of derivatives in space of magnetic field components. Furthermore, the concept of bidirectional MFM enables a direct, fast, and quantitative real space mapping of field component derivatives in both the perpendicular and a lateral direction [1, 2]. It relies solely on multiple-mode flexural cantilever oscillations.

Here, we present a new quantitative approach that enables the mapping of one component of the magnetic stray field in real space. This technique is based on the integration of field derivative maps measured at different scan heights. Furthermore, we combine the ease-of-detection and stability of standard cantilevers with the high sensitivity of nanowire mechanical resonators by applying our recently developed co-resonant sensor concept [3] to MFM. The basis of our MFM probes are iron-filled carbon nanotubes that constitute both nanoscale mechanical resonators and monopole-type magnetic probes.

[1] T. Mühl et al., Appl. Phys. Lett. 101, 112401 (2012).
[2] C. F. Reiche et al., New J. Phys. 17, 013014 (2015).
[3] C. F. Reiche et al., Nanotechnology 26, 335501 (2015).

MA 46.6 Thu 16:45 H33

Ultra-thin Magnetic Angle Sensor for On-Skin Interactive Electronics — •Gilbert Santiago Cañón Bermúdez, Dmitriy Karnaushenko, Daniil Karnaushenko, Denys Makarov, and Oliver G. Schmidt — Institute for Integrative Nanosciences, IFW Dresden, Dresden, Germany

Next generation flexible electronic devices aim to become fully autonomous and will require ultra-thin[1] and flexible navigation modules which often rely on magnetic angular sensors for position tracking. Unfortunately, current angle sensors are too thick and rigid, limiting their direct applicability in flexible electronics. In addition, their reliance on magnetically oriented sensing elements complicates their fabrication. Here, we address these challenges by introducing a novel ultra-thin angle sensor, which uses a puzzle-like approach to selectively orient and bond inorganic spin valve stacks onto ultra-thin polymeric films. This method allows us to produce angle detecting devices with thicknesses below 10 um. Furthermore, due to the excellent thermal stability of the polymer film, it is even possible to directly solder to the sensor contacts. Our experiments show that this ultra-thin sensor can withstand harsh treatment conditions while keeping its angle detection functionality. Moreover, it can be mounted on any curved surface or integrated directly on skin as an imperceptible sensoric aid. This feat opens a new door for interactive devices with magnetic cognition which could enhance the perceptual experience of both visually impaired and non-impaired individuals.

[1] M. Melzer et al., Nat. Commun. 6, 6080 (2015).

15 min. break

MA 46.7 Thu 17:15 H33

All-Electric Access to the Magnetic-Field-Invariant Magnetization of Antiferromagnets — •Tobias Kosub[1,2], Martin Kopte[1,2], Oliver G. Schmidt[1], and Denys Makarov[1,2] — [1]IFW Dresden, 01069 Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, 01239 Dresden, Germany

The rich physics of thin film antiferromagnets can be harnessed for prospective spintronic devices given that all-electric assessment of the tiny uncompensated magnetic moment is achieved. On the example of magnetoelectric antiferromagnetic Cr2O3, we prove that spinning-current anomalous Hall magnetometry serves as an all-electric method to probe the field-invariant uncompensated magnetization of antiferromagnets [1].

We obtain direct access to the surface magnetization of magnetoelectric antiferromagnets providing a read-out method for ferromagnet-free magnetoelectric memory. Owing to the great sensitivity, the technique bears a strong potential to address the physics of antiferromagnets in pristine environments. Exemplarily, we apply the method to access the criticality of the magnetic transition for a Cr2O3 thin film and we reveal the presence of field-invariant uncompensated magnetization even in 6-nm-thin IrMn films clearly distinguishing two contributions. This measurement technique is likely to advance the fundamental understanding of the anomalous Hall and magnetic proximity effects.

Supported by the EU FP7 (ERC Grant No. 306277) and the EU FET Programme (Grant No. 618083).

[1] T. Kosub et al., Phys. Rev. Lett. 115 097201 (2015).

MA 46.8 Thu 17:30 H33

Neutron depolarization imaging of the pressure dependence of $HgCr_2Se_4$ — •Pau Jorba[1], Philipp Schmakat[1], Michael Wagner[1], Alexander Regnat[1], Michael Schulz[2], Vladimir Tsurkan[3], Alois Loidl[3], Peter Böni[1], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik Department, Garching, Germany — [2]Technische Universität München, Forschungsneutronenquelle Heinz Maier Leibnitz, Garching, Germany — [3]University of Augsburg, Center for Electronic Correlations and Magnetism, Augsburg, Germany

The isostructural family of the Chromium spinels (ACr_2X_4) show diverse magnetic ground states due to an interesting variety of competing magnetic interactions between the chromium ions. We report the magnetization of ferromagnetic mercury chromium spinel $HgCr_2Se_4$ up to 1.7 GPa. To extend these data we used high pressure neutron depolarization measurements, allowing us to quantify the evolution of ferromagnetic domains up to 4 GPa and down to very low temperatures. Surprisingly, the critical temperature displays a complex phase diagram, pointing to a loss of ferromagnetism above 3 GPa. Our results demonstrate, on a proof of principle level, the feasibility of combining miniaturized moissanite anvil cells, with neutron depolarization imaging. This paves the way for studies of ferromagnetic and superconducting phases up to very high pressures in a rather simple manner.

MA 46.9 Thu 17:45 H33

The Magnonic Heat Capacity measured by Ferromagnetic Resonance in Metastable Magnetic States — •Benjamin Zingsem, Sabrina Masur, Paul Wendtland, Michael Winklhofer, Markus Ernst Gruner, Ruslan Salikhov, Florian M. Römer, Ralf Meckenstock, and Michael Farle — Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, 47057 Duisburg, Germany

We report on ferromagnetic resonance (FMR) in metastable states and show experimentally that resonant absorption in such magnetic states can be achieved via unconventional angular dependent FMR measurements. Calculations of such an unconventional FMR are compared to experimental results obtained from a 10 nm Fe thin film measured in X-band at temperatures ranging from 50 K to 300 K. In this comparison we find a difference between the critical field and angle configurations at which the metastable states spontaneously decay. We interpret this difference in terms of thermal fluctuations in the real physical system. By applying spin wave theory to calculate the magnonic heat capacity [1] we show that the temperature derivative of the Zeeman energy at these critical points in the experiment is proportional to the magnonic heat capacity, while the difference in the applied field strength at a given angle is given by the thermal fluctuation field [2]. [1] S. M. Rezende et al. Phys. Rev. B, 91 (2015) 104416 [2] S. Bance et al. Applied Physics Letters, 105 (2014)

MA 46.10 Thu 18:00 H33

A co-resonantly coupled sensor for cantilever magnetometry — •Julia Körner[1], Christopher F. Reiche[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

Cantilever magnetometry as a technique to study magnetic properties of samples requires advances due to continuously decreasing sample size. We are presenting a novel approach based on the coupling of a micro- and a nanocantilever with matched resonance frequencies which induces a strong interplay between the two cantilevers [1]. This leads to the possibility of detecting very small magnetic interactions between a sample attached to the highly sensitive nanocantilever and an external magnetic field by measuring the oscillatory state of the microcantilever. We validated the concept by using a commercially availabe silicon cantilever as micrometer sized oscillator and an iron filled carbon nanotube as nanocantilever. Our measurements show an increase in signal strength by several orders of magnitude compared to cantilever magnetometry experiments with similar nanomagnets. With this experiment we do not only demonstrate the functionality of our sensor design but also its potential for very sensitive magnetometry measurements while maintaining a facile oscillation detection with a conventional microcantilever setup [2].

[1] Reiche, Körner et al., Nanotechnology 26 (335501), 2015

[2] Körner et al., submitted to Nanotechnology

MA 46.11 Thu 18:15 H33

Identical wavelength-dependent magnetooptical response of ultrathin permalloy films in multilayer structures on different substrates — Rajkumar Patra[1], Danilo Bürger[1], Roland Mattheis[2], Hartmut Stöcker[3], Fangbin Han[4], Bin Peng[4], Wenxu Zhang[4], Manuel Monecke[5], Georgeta Salvan[5], Stefan Pofahl[6], Rudolf Schäfer[6], Oliver G. Schmidt[1,7], and •Heidemarie Schmidt[1] — [1]Fakultät ETIT, TU Chemnitz — [2]IPHT Jena — [3]TU BA Freiberg — [4]UESTC, China — [5]Fakultät Physik, TU Chemnitz — [6]Metallic Materials, IFW Dresden — [7]Integrative Nanosciences, IFW Dresden

The multilayer systems discussed in this work consist of Ru/permalloy (Py)/Ta stacks on different substrates, namely SiO2/Si and ZnO. The wavelength-dependent on-diagonal elements of the dielectric tensors of all layers in the multilayer systems have been determined from standard ellipsometry measurements and modelling. Below Curie temperature, the wavelength-dependent off-diagonal elements of the dielectric tensor of the Py films are non-zero and odd functions of magnetization. Therefore, we applied vector magnetooptical generalized ellipsometry with a 0.4 T octupole magnet [1] to study the optical anisotropy of the multilayer structures and employed the 4x4 matrix algorithm to characterize the directly measured 4x4 Mueller matrix and to extract the thickness-independent dielectric tensor [2] of the Py thin films. [1] K. Mok, N. Du, H. Schmidt, Rev. Sci. Instr. 82 (2011) 033112; [2] K. Mok, H. Schmidt et al. J. Appl. Phys. 110 (2011) 123110; Phys. Rev. B 84 (2011) 094413

MA 47: Multiferroics II (jointly with DF, KR, TT)

Time: Thursday 15:00–17:30 Location: H34

MA 47.1 Thu 15:00 H34

Skyrmionic and ferromagnetic resonances in magnetoelectric Cu_2OSeO_3 - magnetic vs electric fields — •S. Harms[1], M. Belesi[2], H. Berger[3], J.-F. Ansermet[3], C. Grams[1], P. Becker[1], and J. Hemberger[1] — [1]University of Cologne, Germany — [2]IFW, Dresden, Germany — [3]ICMP, EPFL, Lausanne, Switzerland

Magnetic Skyrmions are topologically stable spin whirls stabilized by spin-orbit interaction in chiral cubic magnets. It has been shown, that skyrmionic structures can be efficiently manipulated by small forces, such as e.g. currents in metallic host materials [1]. It was also shown, that the skyrmion phases in general can be excited by AC magnetic fields in the microwave range. [2].
The magnetoelectric helimagnetic insulator Cu_2OSeO_3 is one of the up to now rare cases of an insulating chiral magnets showing a stable skyrmion lattice embedded in between helical and ferrimagnetic phases. In this compound the lack of magnetic inversion symmetry leads to the occurrence of electric polarization and correspondingly to a magnetoelectric response. We present results of broadband spectroscopy up to 5 GHz trying to disentangle the different influence of electric and magnetic fields.

Funded through the Institutional Strategy of the University of Cologne within the German Excellence Initiative.

[1] T. Schulz et al., Nature Physics 8, 301-304 (2012).
[2] Y. Onose et al., Phys. Rev. Lett. 109, 037603 (2012).

MA 47.2 Thu 15:15 H34

Multiferroic vs. magnetoelectric properties of the dilution series $[(NH_4)_{1-x}K_x]_2[FeCl_5(H_2O)]$ — •Daniel Brüning[1], Matthias Ackermann[1], Ladislav Bohaty[2], Petra Becker[2], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Insitut für Kristallographie, Universität zu Köln, Germany

Recently we found that $(NH_4)_2[FeCl_5(H_2O)]$, a member of the antiferromagnetic erythrosiderites $A_2[FeX_5(H_2O)]$ (A = K, Rb, Cs or NH_4 and X = Cl or Br) is multiferroic with a spontaneous polarization at T_C = 6.87K, slightly below the magnetic ordering at T_N = 7.25K. Additionally we found a high-temperature structural phase transition T_{st} = 79K, related to a monoclinic distortion (Pnma to $P11\frac{2}{a}$) due to a rearrangement of the hydrogen atoms. In contrast to $(NH_4)_2[FeCl_5(H_2O)]$, the related erythrosiderites with A = K, Rb or Cs are not multiferroic, but show linear magnetoelectric coupling with $P_i = \alpha_{ij} H_j$ below T_N. Investigating the dilution series with $A = (NH_4)_{1-x}K_x$ provides information on the stability of the multiferroic versus magnetoelectric behavior. Based on dielectric and magnetic measurements we present detailed magnetic-field versus temperature phase diagrams. Interestingly, the mixed crystals develop a finite pyroelectric polarization at T_{st}, whereas there is no indication of pyroelectricity above T_N, neither in the pure (NH_4)-based nor in the pure K-based compound.

M. Ackermann et al., J. Phys.: Condens. Matter, **26**, 506002, (2014)
M. Ackermann et al., New J. Phys., **15** 123001, (2013)

MA 47.3 Thu 15:30 H34

Optical switching of multiferroic domains in $TbMnO_3$ — •Sebastian Manz[1], Masakazu Matsubara[1,2], Jonathan Büchi[1], Thomas Lottermoser[1], Ayato Iyama[3], Tsuyoshi Kimura[3], Dennis Meier[1], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, 8093 Zurich, Switzerland — [2]Department of Physics, Tohoku University, Sendai 980-8578, Japan — [3]Division of Materials Physics, Osaka University, Osaka 560-8531, Japan

Multiferroics with spin-spiral-driven ferroelectricity possess a strong coupling between electric and magnetic domains, rendering them interesting for future technological devices. Controlling these domains on the local scale is an essential prerequisite, e. g. for data storage applications. Current discussions on spin-spiral multiferroics, however, focused on the conversion of one domain state into the other but reversible local manipulation has not been shown yet. As presently demonstrated in ferri- and ferromagnets, all-optical switching offers a promising route to achieve localized control. Here, we demonstrate spatially-resolved optical switching of antiferromagnetism in multiferroic $TbMnO_3$. We manipulate the antiferromagnetic order via the coupled ferroelectric state using a unique relation between the wavelength of the light and the induced polarization change. This allows us to realize reversible switching of multiferroic domains without any external bias fields. To further understand our results, we performed Monte-Carlo simulations which confirmed our findings. Our proof-of-principle experiments show that multiferroic domains and therefore domain walls can be generated and erased entirely optically on the local scale.

MA 47.4 Thu 15:45 H34

Investigation of the photostriction effect in $BiFeO_3$ by means of infrared and optical spectroscopy — •Florian Burkert and Christine Kuntscher — Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany

It has been reported that $BiFeO_3$ crystals change their size during illumination with visible light or ultraviolet radiation [1,2]. We studied the impact of this photostrictive effect on the optical properties of a $BiFeO_3$ single crystal in the infrared up to the ultraviolet frequency range by using an FTIR spectrometer and a CCD spectrograph. During illumination with various radiation sources we observe the appearance of additional absorption features in the optical spectra. We will discuss possible origins of these new features.

[1] B. Kundys et al., Nat. Mater. **9**, 803 (2010)
[2] B. Kundys et al., Phys. Rev. B **85**, 092301 (2012)

15 min. break

MA 47.5 Thu 16:15 H34

Epitaxial engineering of ferrimagnetic $3d$-$5d$ double perovskites as templates for single phase multiferroics — •Vikas Shabadi[1], Ashish Kulkarni[1,2], Philipp Komissinskiy[1], Ivetta Slipukhina[3], Robert Paria Sena[4], Joke Hadermann[4], Rajeev Gupta[2], Hongbin Zhang[1], Marjana Ležaić[3], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, Germany — [2]Materials Science Programme, IIT Kanpur, India — [3]Peter Grünberg Institut, Forschungzentrum Jülich and JARA, Germany — [4]Electron Microscopy for Materials Science (EMAT), University of Antwerp, Belgium

$3d$-$5d$ double perovskites ($A_2BB'O_6$) are of high interest due to the possible large magnetic ordering temperatures [1], multiferroicity, and the influence of spin-orbit coupling. We have for the first time synthesized in thin film form double perovskites with Mn^{2+}/Re^{4+} and Ni^{2+}/Re^{4+} cations at the B/B'-sites and La^{3+} at the A-site, previously predicted by density functional theory (DFT). We have shown the almost perfect ordering at the B-site by X-ray diffraction and high-angle annular dark field scanning transmission electron microscopy. The magnetic properties of the compounds studied by SQUID magnetometry and element specific X-Ray magnetic circular dichroism (XMCD) confirm a robust ferrimagnetic order in agreement with the DFT calculations. The results provide a valuable framework for engineering new single-phase multiferroics with ferroelectrically active A-site cations.

[1] Y. Krockenberger *et al.*, Phys. Rev. B **75**, 020404(R) (2007).

MA 47.6 Thu 16:30 H34

Structural and magnetic properties of orthorombic $ErFeO_3$ from first principles — •Dominik M. Juraschek and Nicola A. Spaldin — Materials Theory, ETH Zürich, Switzerland

We investigate the structural and magnetic properties of orthorhombic $ErFeO_3$ using density functional theory.

Rare-earth orthoferrites ($RFeO_3$) show complex coupled lattice and magnetic properties leading to interesting multifferoic, magnetoelectric and spin-dynamic behaviour.

We find that the PBEsol implementation of the generalized gradient approximation plus Hubbard U (GGA+U) method gives structural properties in good agreement with experiment. Using this approximation, we calculate the lattice dynamical properties, the magnetic ground state and the spin-phonon coupling. Our DFT calculations with erbium's 4f electrons frozen in the pseudopotential cores reproduce the G_x-type antiferromagnetic ordering with weak ferromagnetic F_z canting that is observed experimentally at high temperatures. This lends support to the proposal that the observed spin reorientation transition at 100 K to a G_z ordering is mediately coupling to erbium's 4f moments.

MA 47.7 Thu 16:45 H34

First-principles calculations on anion doped GaFeO3 — •Jacqueline Atanelov and Peter Mohn — Technische Universität Wien, Institut für Angewandte Physik, Computational Materials Science

We present ab initio DFT calculations performed on stoichiometric and anion doped GaFeO3 substituting O by a C, N and S atom, respectively. Stoichiometric GaFeO3 has an antiferromagnetic (AFM) ground state. The Fe atoms of the sublattices Fe1 and Fe2 couple antiferromagnetically via the O atoms through the superexchange mechanism. Exchanging the for the superexchange important O atom with p-elements of a different valence electron configuration changes the underlying magnetic exchange mechanism and influence the ground state properties which can be used for tuning properties interesting for technical applications. Four different doping configurations were examined revealing a cell site dependent influence on the magnetic properties. Carbon, for example, changes the AFM coupling present in the Fe1-O-Fe2 configuration into a ferrimagnetic exchange for the Fe1-C-Fe2 bond. Depending on the respective cell site C substitution introduces a ferrimagnetic or AFM ground state. Nitrogen alters the ground state magnetic moment as well and Sulfur introduces large structural distortions affecting the, band gap and the overall AFM coupling inside the doped GaFeO3 simulation cell. We give a detailed discussion on the respective magnetic exchange mechanisms and electronic properties with regard to applications as photocatalysis and use the predictive power of ab initio DFT simulations that may trigger future experiments.

MA 47.8 Thu 17:00 H34

Multiferroicity in off-stoichiometric $Ga_xFe_{1-x}O_3$ — •Konstantin Z. Rushchanskii, Stefan Blügel, and Marjana Ležaić — Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The recently reported observation of room-temperature mutiferroic behavior in $Ga_{0.6}Fe_{1.4}O_3$ (GFO) [1] and ϵ-Fe_2O_3 (eFO) [2] offers new perspectives for electronic devices whose operation is based on the switching of magnetic and electric ferroic ordering, as well as on the strong interaction between the magnetic and ferroelectric order parameters, such as multistate non-volatile memory cells. Unfortunately, the realistic microscopic switching mechanism in still not known for either of these materials. They are isostructural with polar $Pna2_1$ crystalline symmetry. In GFO, disorder in the occupancy of Ga and Fe sites is present, whereas eFO is a fully ordered compound. Their parallel study allows us to understand the influence of disorder on possible ferroelectric properties, and develop criteria to maximize the effect. We will present the results of an evolutionary-algorithm [3] based study of $GaFeO_3$-Fe_2O_3 solid solutions, (i.e., with increasing iron content). We will show the condition at which the proper ferroelectricity arises in GFO multiferroics and characterize the parameters of the ferroelectric phase transition. – We acknowledge financial support by Helmholtz Young Investigators Group Programme VH-NG-409 and through DFG-ANR (GALIMEO Consortium).

[1] A. Thomasson *et al.*, J. Appl. Phys. **113**, 214101 (2013); [2] M. Gich *et al.*, Adv. Mater., **26**, 4645 (2014); [3] http://uspex.stonybrook.edu

MA 47.9 Thu 17:15 H34

Fine-tuning ferroic properties: an X-ray diffraction study of type-II multiferroics — •Yoav William Windsor[1], Mahesh Ramakrishnan[1], Kenta Shimamoto[2], Aurora Alberca[1], Laurenz Rettig[1], Elisabeth Monica Bothschafter[1], Yi Hu[2], Thomas Lippert[2], Christof Schneider[2], and Urs Staub[1] — [1]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]General Energy Research Department, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

We present a complete X-ray diffraction study of high-quality crystalline films of a prototypical multiferroic, using soft and hard X-rays. With the prospect of future multiferroic functionalities in mind, we show that epitaxial strain directly controls both of the system's ferroic properties. We demonstrate that strain can be used to "push" the system between different multiferroic phases, and even to fine-tune the magnetic ordering periodicity. We generalize this to show that manipulating the crystal structure by other means allows fine-tuning the ferroic properties in a similar manner.

MA 48: Poster Session II

Magnetization Dynamics, Spin-Torque and -Transport Phenomena,Topological Insulators, Micromagnetic simulations

Time: Thursday 15:00–18:00 Location: Poster B1

MA 48.1 Thu 15:00 Poster B1

Multi-Scale Magnetic Vortex Core Switching — •Andrea De Lucia, Mathias Kläui, and Benjamin Krüger — Johannes Gutenberg Universität, Mainz, Germany

Simulations of magnetization dynamics in a multi-scale environment enable rapid evaluation of the Landau-Lifshitz-Gilbert equation in a mesoscopic sample with nanoscopic accuracy in the regions where such accuracy is needed. Here a multi-scale magnetization dynamics simulation scheme was developed and applied to systems with special spin structures and properties. To achieve this, the MicroMagnum simulator was used as a starting point and then expanded to include a multi-scale solving routine. The software selectively simulates different regions of a ferromagnetic sample according to their properties in order to employ the most suitable discretization and model for each. The method was used to investigate the effect of unipolar magnetic pulses for reliable switching of the core of a magnetic vortex. The switching was simulated for a Permalloy disk with a radius of 100 nm. The parameter range for switch of this device is shown. The core switching is mediated by the creation of a vortex-antivortex pair and the following annihilation of the original vortex with the antivortex. This process can be shown with unprecedented accuracy due to the multi-scale nature of the simulator. The presented results show that magnetic vortices can be reliably switched between two energetically degenerate, stable, polarization states by pulses with certain combinations of width and intensity that we determine with an unprecedented accuracy due to the multi-scale approach.

MA 48.2 Thu 15:00 Poster B1

Magnetic properties of Ce^{3+} ions in Nb-doped cerium dioxide — •Olga Gornostaeva[1] and Taras Kolodiazhnyi[2] — [1]Donetsk National University, Vinnytsia, Ukraine — [2]National Institute for Materials Science, Tsukuba, Japan

Dilute magnetic oxides are currently attracting much attention in view of their potential for applications in spintronics and magneto-optical devices. In particular, it relates doped cerium dioxide. We have performed theoretical and experimental studies of crystal-field effects on magnetic properties of Nb-doped CeO_2. Using the crystallographic data for the abovementioned compound and the modified crystal-field theory, a novel computational approach, we have calculated energy levels of the Ce^{3+} ions and g-factor values. It was found that the Γ_8 ground state is separated from the overlying Γ_7 state by 173 cm^{-1} in good agreement with the optical transmission data. With the g-factor value and related experimental data, we found the Curie-Weiss constant and get a percentage of Ce^{3+} ions in a mole of the substance. Comparison of calculated and experimentally measured temperature dependences of the magnetic susceptibility in Nb-doped and undoped cerium dioxide allowed us to estimate the contribution of Ce^{3+} ions to the magnetism of the dilute magnetic oxide.

MA 48.3 Thu 15:00 Poster B1

Tunable 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 a density functional theory based guideline how to combine

local magnetism represented by single molecule magnets (SMMs), with the three-dimensional nature of metal organic frameworks (MOFs). Recently, the electronic and magnetic structure of the flexible MOF DUT-8(Ni) was described by Trepte et al. [1]. Based on our previous work we performed a screening of the metal centers in a model system, which is a good approximation for the secondary building unit (SBU) of DUT-8(Ni). The main result of these calculations is, that the electronic structure of this SBU is mainly determined and influenced by the metal centers (3d metals). By varying the metal centers we are able to tune the magnetic properties and obtain stable non-magnetic, ferromagnetic, anti-ferromagnetic or eventually even metallic SBU.
[1] K. Trepte, S. Schwalbe and G. Seifert, PhysChemChemPhys, vol. 17, pp. 17122-17129, 2015

MA 48.4 Thu 15:00 Poster B1

Theoretical investigations of ^{129}Xe NMR in UiO-66 and UiO-67 — •Kai Trepte[1], Jana Schaber[2], Eike Brunner[2], and Gotthard Seifert[1] — [1]Technische Universität Dresden, Theoretical Chemistry, Germany — [2]Technische Universität Dresden, Bioanalytical Chemistry, Germany

The chemical shift of the isotope ^{129}Xe inside the metal organic frameworks (MOFs) UiO-66/UiO-67 (UiO - University of Oslo) has been investigated using density functional theory. Those structures are known for their high thermal and chemical stability [1]. Both MOFs form two types of pores (tetrahedral (T) and octahedral (O) ones), which provide different chemical environments for absorbed Xe atoms. The mentioned isotope of Xe has several advantages in NMR (nuclear magnetic resonance) investigations, as it tends to be mononuclear, chemically inert and has a nuclear spin of $I = 1/2$. T. Ito and J. Fraissard [2] described the Xe shift inside zeolites as a composition of different influences. Some of these influences are interatomic interactions like Xe-Xe and Xe-surface effects, which can be summed up to gain the total shift. Several model systems have been generated to reduce calculation time and verify this additive behaviour. Additionally, theoretical investigations of Xe inside the crystalline systems allow a separation of the shift as introduced by the different pores. Our results are compared to experimental values to get a deeper insight into the effects on the Xe shift and explain the experimentally observed chemical shift.
[1] Chavan et al., PhysChemChemPhys, 2012, vol.14, pp.1614-1626
[2] T. Ito and J. Fraissard, J. Chem. Phys., vol.76, pp.5225-5229, 1982

MA 48.5 Thu 15:00 Poster B1

Atomistic spin dynamics simulations of chiral spin structures at surfaces — •Stephan von Malottki, Bertrand Dupé, and Stefan Heinze — Institut für Theoretische Physik und Astrophysik der Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24118 Kiel, Germany

Chiral magnetic structures on surfaces such as domain walls or skrymions are promising candidates for spintronic devices [1]. Therefore, it is of great interest to understand the formation, stability and motion under external stimuli of such spin structures. In order to study these issues, we perform atomistic spin dynamics simulations, based on a numerical solution of the Landau-Lifshitz-Gilbert-equation. We consider the interplay of exchange and Dzyaloshinskii-Moriya interaction in spin structures at surfaces as well as the magnetocrystalline anisotropy. We treat exchange interactions beyond an effective exchange coupling, allowing to tackle systems in which frustration due to competing ferro- and antiferromagnetic coupling is important [3]. Additionally, higher order exchange interactions, namely the 4-spin and biquadratic interaction, are considered. We study the dynamics of chiral spin structures under external magnetic or electric fields, as well as with spin polarized electrical currents.

[1] A. Fert *et al.*, Nature Nanotech **8** (2013). [2] J. H. Mentink *et al.*, J. Phys.: Condens. Matter **22** (2010). [3] B. Dupé *et al.*, arXiv:1503.08098 (2015).

MA 48.6 Thu 15:00 Poster B1

A General Analytic Description of the Ferromagnetic High Frequency Susceptibility — •Benjamin Zingsem, Michael Winklhofer, Ralf Meckenstock, and Michael Farle — Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, 47057 Duisburg, Germany

We present a general analytic solution of the ferromagnetic high frequency susceptibility tensor in ferromagnetic systems with arbritrary free energy landscapes. In contrast to conventional approaches found throughout literature, we do not solve the Landau-Lifshitz-Gilbert-equation as a linear system of equations. Instead we employ the jacobian of the system in the perturbation to obtain the tensor with the well known Polder Ansatz. Thus we do not need to make assumptions on the entries of the tensor and the form of the free energy is left arbitray. This complete tensor allows for accurate and fast calculations of the high frequency susceptibility as a function of the applied field angle and amplitude as well as the frequency or any other physical parameter. Furthermore it allows for the description of asymetric lineshapes as well as lineshapes in non extremal magnetic directions. We also tackle the problem of finding the equilibrium states of the magnetization that are necessary in the calculation of the tensor in an unconventional way, suggesting a trajectory dependent second order newton algorithm. In addition to this we are able to calculate the magnon dispersion in reciprocal space as a density function, by applying the Suhl ansatz and including the diploar and the exchange contibution in the energy landscape.

MA 48.7 Thu 15:00 Poster B1

Static and dynamic magnetization of Fe_3O_4 nano cubes — •Thomas Feggeler, Zi-An Li, Alexandra Terwey, Michael Winklhofer, Ralf Meckenstock, and Michael Farle — Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg.

Micromagnetic simulations of the relaxation of the magnetization and the stray field distribution of various ensembles of cube-shaped Fe_3O_4 nanoparticles (edge length of $\sim$ 70 nm) were performed to support the results obtained from magnetic imaging with a transmission electron microscope. The simulation matches the experimental data and allows to extract the magnetic parameters quantitatively (e. g. for a chain of 4 particles: magnetization M $\approx$ 11002.67 A/m, energy densities: $E_{Demag} \approx 477.93$ J/m^3, $E_{Exch} \approx 47.51$ J/m^3, $E_{MAE} \approx -15.98$ J/m^3). The dependence of the effective magnetic anisotropy energy density (MAE) and dipolar interaction on the orientation of the magnetization will be discussed.

In support of ferromagnetic resonance (FMR) measurements on single magnetic bacteria, which contain chains of various numbers of Fe_3O_4 nano particles, FMR-simulations of corresponding simplified particle chains were done. Non-uniform collective FMR excitations and the influence of dipolar coupling on the FMR in the particle chains can be clearly identified and quantified.

MA 48.8 Thu 15:00 Poster B1

Enhancement of the spin-wave propagation distance in microstructures by localized parallel parametric amplification — •Frank Heussner[1], Thomas Brächer[2], Philipp Pirro[3], Thomas Meyer[1], Tobias Fischer[1], Moritz Geilen[1], Björn Heinz[1], Bert Lägel[1], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaisersautern, Germany — [2]Univ. Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, 38054 Grenoble, France — [3]Institut Jean Lamour, Université Lorraine, CNRS, 54506 Vandoeuvre-lès-Nancy, France

We report on the localized parallel parametric amplification of a coherent spin wave in the non-adiabatic regime. We demonstrate that due to the co-propagating parametrically created magnons a strong enhancement of the propagation distance of the input spin wave can be realized. A microwave current flowing inside a transmission line with modulated width placed underneath the transversely magnetized $Ni_{81}Fe_{19}$ waveguide creates an alternating magnetic field, which is locally enhanced at the position of the narrowing. Only in the area of this locally enhanced field effective parametric pumping takes place. In addition to the strong amplification in the non-adiabatic regime, we show that the localization of the pumping field leads to a high signal-to-noise ratio of the amplification process behind the amplification area. Our results show that localized parallel parametric amplification recommends itself for applications in future spintronic devices to overcome the limitations due to a limited spin-wave propagation distance.

MA 48.9 Thu 15:00 Poster B1

Magnon supercurrent in a magnon Bose-Einstein condensate subject to a thermal gradient — •Dmytro A. Bozhko[1,2], Peter Clausen[1], Vitaliy I. Vasyuchka[1], Gennadii A. Melkov[3], Burkard Hillebrands[1], Victor S. L'vov[4], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Taras Shevchenko National University of Kyiv, Ukraine — [4]Weizmann Institute of Science, Israel

Bose-Einstein magnon condensation (BEC), the spontaneous appearance of a coherent state at the global energy minima of the spin-wave spectrum possesses zero group velocity. The presented here dynamics of a magnon BEC in a thermal gradient provides the first evidence of the formation of a magnon supercurrent at room temperature. The magnon dynamics was revealed by time- and wavevector-resolved Brillouin light scattering spectroscopy. It has been found that the freely evolving magnon BEC in a parametrically pumped spin system of a single-crystal film of yttrium iron garnet decays faster with the increase of a probing laser beam power. The behavior of the rest of the magnon gas remains undisturbed. A uniform sample heating does not affect the BEC behavior. Thus, the observed effect can be treated as the outflow of condensed magnons from the laser focal point due to the phase difference induced in the BEC wave function by a temperature gradient. The developed theoretical model perfectly describes the experimental data. The work is supported by the DFG within the SFB/TR 49.

MA 48.10 Thu 15:00 Poster B1

Ultrafast magnetization dynamics in thin Co films studied by spin-resolved photoelectron spectroscopy with XUV pulses from HHG — •Sebastian Emmerich[1], Moritz Plötzing[2], Steffen Eich[1], Markus Rollinger[1], Roman Adam[2], Cong Chen[3], Henry Kapteyn[3], Margret Murnane[3], Benjamin Stadtmüller[1], Mirko Cinchetti[1], Martin Aeschlimann[1], Stefan Mathias[1,4], and Claus Schneider[2] — [1]University of Kaiserslautern and Research Center OPTIMAS, Kaiserslautern, Germany — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institut, Jülich, Germany — [3]JILA and NIST, University of Colorado, Boulder, USA — [4]Georg-August-Universität Göttingen, I. Physikalisches Institut, Göttingen, Germany

We combine a bright 10 kHz high-order harmonic generation light source with an exchange scattering-based spin detector to investigate ultrafast magnetization dynamics in thin Co films. We map the spin-resolved band structure dynamics over the full valence band energy during the ultrafast demagnetization process following photoexcitation with a 1.57 eV pump pulse. We observe a >50% quenching of the spin polarization within the first 50 fs after the optical excitation, which is simultaneously occurring over the whole energy range. This finding gives strong evidence that the initial ultrafast demagnetization dynamics of the valence band in thin Co films is dominated by spin-mixing processes. A reduction of the exchange splitting, as expected in the Stoner model, is not observed.

MA 48.11 Thu 15:00 Poster B1

Spin pumping at structurally engineered interfaces — •Sascha Keller[1], Laura Mihalceanu[1], Andres Conca[1], Matthias R. Schweizer[1], Jörg Lösch[2], Burkard Hillebrands[1], and Evangelos Th. Papaioannou[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Institut für Oberflächen- und Schichtanalytik (IFOS), Trippstadter Str. 120, 67663 Kaiserslautern, Germany

The spin pumping effect allows for the injection of a spin current from a ferromagnetic (FM) layer at ferromagnetic resonance (FMR) into an attached non-magnetic metal (NM) layer. The spin current is then subsequently transformed into a charge current by the inverse spin Hall effect (ISHE) inside the NM layer. Epitaxially grown FM/NM interfaces can strongly affect the spin pumping effect due to the structural quality of the interface and the intrinsic magnetic anisotropy of the FM. In this work we address the manipulation of these effects by structurally engineering the interfaces in a Fe/Pt model system. We show how spin pumping is affected with respect to crystal symmetry of the interface, grain size, Pt layer thickness and different capping layers (MgO, Pd and Au). Furthermore we analyze the shielding effect of Pt in the sub-skin-depth regime as well as rectification effects that are occurring with microwave excitation which are superimposed to the ISHE signal. Financial support by the Carl Zeiss Stiftung is gratefully acknowledged.

MA 48.12 Thu 15:00 Poster B1

Time-resolved spontaneous Raman scattering in complex materials — •Christoph Boguschewski, Rolf B. Versteeg, Prashant Padmanabhan, Thomas Koethe, Jingyi Zhu, and Paul H.M. van Loosdrecht — II. Physikalisches Institut - Universität zu Köln, Zülpicher Straße 77, 50937 Cologne, Germany

Complex materials show a strong interplay between different degrees of freedom giving rise to a variety of intriguing ground states, and novel excitations. Raman spectroscopy allows to measure these excitations and to determine the symmetry of the probed ground state. Expanding the Raman spectroscopy technique into the time domain opens up new opportunities to study symmetry changes following optically induced phase transitions, to probe quasiparticle population statistics of unconventional ground states on ultrafast timescales, and to address fundamental questions regarding angular momentum transfer in complex materials.

Here, we present our newly constructed time-resolved, high spectral resolution Raman spectroscopy system, fully dedicated to the study of complex matter within the picosecond temporal regime. An overview of our first results on quasiparticle scattering in antiferromagnetic materials is presented.

MA 48.13 Thu 15:00 Poster B1

Realization of a Spin-Wave Majority Gate — •Tobias Fischer[1], Martin Kewenig[1], Dmytro A. Bozhko[1], Andrii V. Chumak[1], Alexander A. Serga[1], Ihor I. Syvorotka[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Crystal Physics and Technology, Scientific Research Company *Carat*, Lviv, Ukraine

By promising a significant reduction of Joule heating due to Ohmic losses, spin-wave logic devices offer large advantages compared to modern CMOS-based elements. Also, a majority-based logic allows for a reduction of the number of gates for implementing a given operation [1]. The magnetic insulator material yttrium iron garnet (YIG) is of particular interest for applications in this field due to its intrinsically low Gilbert damping parameter and large spin-wave propagation lengths.

In this work, we present the investigation of a macroscopic spin-wave majority gate device made from YIG films. We examine the spin-wave-propagation by means of microwave techniques.

In order to analyze the operational properties of our device, we determine the coupling among the input channels and study the dependence of the output signal amplitude and phase on the parameters of the input signals.

Financial support by EU-FET (Grant InSpin 612759) is acknowledged.

[1] A. Khitun *et al.*, J. Phys. D: Appl. Phys. **43** (2010) 264005

MA 48.14 Thu 15:00 Poster B1

Magnetoresistive detection of single magnetic vortices — •Lakshmi Ramasubramanian[1,2], Ciarán Fowley[1], Jürgen Lindner[1], Jürgen Fassbender[1,3], Attila Kákay[1], Stefan Schulz[2], Sibylle Gemming[2], and Alina Maria 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, Elektrotechnik und Informationstechnik, 09126 Chemnitz, Germany. — [3]Institute for Physics of Solids, TU Dresden, 01069 Dresden, Germany

The fundamental oscillation mode of magnetic vortices in thin-film elements has recently been exploited in spin-torque-driven nano-oscillators [A. Wachowiak et al., Science (2002)]. The fundamental frequency is determined by the saturation magnetisation, as well as the geometrical confinement of the magnetisation e.g. the diameter and height of a magnetic disk. The objective of this study is to design magnetic discs, contact them with electrical leads and probe the dynamics of the vortex structures using magnetoresistive detection. By varying the thickness and dimensions of the disk, requirements for the magnetic vortex as a ground state will be determined. The electrical resistance of a single disc is expected to change based on the relative angle between the magnetisation direction and the applied current (the anisotropic magnetoresistance (AMR) effect) [S. Kasai et al, PRL 97, 107204 (2006)]. Using the AMR as a detection technique we will determine if electrical detection of dynamics is feasible in this geometry and its associated limits.

MA 48.15 Thu 15:00 Poster B1

d.c. voltages in Fe/(Ga,Mn)As induced by ferromagnetic resonance — •lin chen, martin decker, robert islinger, markus härtinger, matthias kronseder, dieter schuh, dominique bougeard, christian back, and dieter weiss — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany

The electrical detection of magnetization dynamics is by now a common method in spintronic devices operation. In this work, we investigate the dc voltages occurring in a Fe/(Ga,Mn)As structure under ferromagnetic resonance.

The sample consists of Fe (5 nm) and (Ga,Mn)As (50 nm) grown on GaAs (001) semi-insulating substrate by molecular-beam epitaxy. The Fe/(Ga,Mn)As stripe is integrated between the signal and ground line of the coplanar waveguide, where the ferromagnetic stripe is excited by an out-of-plane magnetic field. The dc voltage is measured as a function of the external magnetic field.

The characteristic dc voltage spectrum can be observed at each magnetic field angle, which can be decomposed into a symmetric Vsym and an anti-symmetric Va-sym component. The two components show distinct difference in their angular dependence. A detailed analysis shows that Va-sym is induced by the anisotropic magnetoresistance (AMR) of Fe; while Vsym is related to spin pumping from Fe into (Ga,Mn)As.

This work is supported by the German Science Foundation (DFG) via SFB 689. L. Chen is also grateful for support from Alexander von Humboldt Foundation.

MA 48.16 Thu 15:00 Poster B1

Versatile approach to the spin dynamics of correlated electrons — Malte Behrmann[1], Alexander I. Lichtenstein[1], Mikhail I. Katsnelson[2], and •Frank Lechermann[3] — [1]I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg — [2]Radboud University Nijmegen, Institute for Molecules and Materials, NL-6525 AJ Nijmegen, The Netherlands — [3]Institut für Keramische Hochleistungswerkstoffe, Technische Universität Hamburg-Harburg, 21073 Hamburg

Most theoretical approaches to time-dependent magnetism in condensed matter either focus on the spin-only limit or rely on a weak-correlation treatment based on band theory. However many experimental studies deal with itinerant local-moment systems, where the intricate coupling between spin and charge excitations within a moderate-to-strong correlation regime plays an important role. We thus here present a novel real-space treatment of the non-equilibrium Hubbard model, suitable to address correlated spin dynamics ranging from the Stoner to the Heisenberg limit. It is based on the time-dependent rotational-invariant slave-boson scheme [1], allowing to keep track of both, local-moment as well as itinerant degrees of freedom. The antiferromagnetic spin-wave spectrum at half filling is obtained in the linear-response limit of the generic non-adiabatic framework. Various examples with and without doping demonstrate the capabilities and potential of the methodology.

[1] M. Behrmann, M. Fabrizio and F. Lechermann, PRB **88**, 035116 (2013)

MA 48.17 Thu 15:00 Poster B1

Ultrafast magnetization dynamics of Gd studied by XMCD in reflection — •Kamil Bobowski[1], Björn Frietsch[1], Markus Gleich[1], Niko Pontius[2], Christian Schüssler-Langeheine[2], Christoph Trabant[1], Marko Wietstruk[1], and Martin Weinelt[1] — [1]Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany

We studied the ultrafast magnetization dynamics of a 10-nm thick single-crystalline Gd(0001) film at the M_4 and M_5 absorption edges using X-ray magnetic circular dichroism (XMCD) in reflection geometry. In a laser-pump X-ray-probe experiment we find a two-step demagnetization behavior which shows similar results to earlier XMCD measurements on polycrystalline Gd [1]. On the fast time scale below 4 ps, we observe an exponential decrease of the sample magnetization with increasing pump laser fluence, while on the slow time scale of 100 ps, the demagnetization is linearly dependent on the pump laser fluence. Here, a critical slowing down of the magnetization dynamics is observed for pump pulse fluences above $8\,\mathrm{mJ/cm^2}$. A simulation based on the microscopic three temperature model (M3TM) of Koopmans et al. [2] does not allow to quantitatively reproduce the first step of the magnetization dynamics.

[1] M. Wietstruk *et. al.*, *Phys. Rev. Lett.* **106**, 127401 (2011).
[2] B. Koopmans *et. al.*, *Nat Mater* **9**, 259-265 (2010).

MA 48.18 Thu 15:00 Poster B1

Towards Ultrafast Magnetic Imaging Using Circularly Polarized High Harmonics — •Christina Nolte[1], Sergey Zayko[2], Sascha Schäfer[2], Daniel Steil[1], Manfred Albrecht[3], Stefan Mathias[1], and Claus Ropers[2] — [1]I. Physikalisches Institut, Universität Göttingen — [2]IV. Physikalisches Institut, Universität Göttingen — [3]Institut für Physik, Universität Augsburg

The recently demonstrated generation of circularly polarized extreme ultraviolet (XUV) 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]. Extending a recent implementation of high-harmonic-based coherent diffractive imaging [4], we will present first results employing circularly polarized harmonics in the 40-70 eV photon energy range.

[1] O. Kfir et al., Nature Photonics 9, 99-105 (2015)
[2] D. Hickstein et al., Nature Photonics 9, 743-750 (2015)
[3] S. Mathias et al., JESRP 189, 164-170 (2013)
[4] S. Zayko et al., Optics Express 23, 19911-19921 (2015)

MA 48.19 Thu 15:00 Poster B1

Spin-current manipulation of photo-induced magnetization dynamics — •Steffen Wittrock[1], Dennis Meyer[1], Markus Müller[1], Henning Ulrichs[1], Jakob Walowski[2], Ulrike Martens[2], and Markus Münzenberg[2] — [1]Georg-August-Universität Göttingen — [2]Ernst-Moritz-Arndt-Universität Greifswald

Spin currents offer a way to control static and dynamic magnetic properties, and therefore they are crucial for next-generation MRAM devices or spin- torque oscillators. Manipulating the dynamics is especially interesting within the context of photo-magnonics. In typical 3d transition metal ferromagnets like CoFeB, the lifetime of light-induced magnetization dynamics is restricted to about 1 ns, which e.g. strongly limits the opportunities to exploit the wave nature in a magnonic crystal filtering device. Here, we investigate the potential of spin-currents to increase the lifetime in a simple trilayer system, consisting of 8 nm β-Tantalum, 5 nm CoFeB, capped by 3 nm Ruthenium. The samples were grown in UHV by magnetron sputtering (Ta, CoFeB) and E-beam evaporation (Ru), and subsequently patterned into micron-sized conduction strips using E-beam-lithography. Due to the spin Hall effect, the Ta layer generates a transverse spin current when a lateral charge current passes through the strip. Using time-resolved all-optical pump-probe spectroscopy, we investigate how this spin current affects the magnetization dynamics in the adjacent CoFeB layer.

MA 48.20 Thu 15:00 Poster B1

Laser-driven ferromagnetic ordering in FeRh — •Robert Carley[1], Sebastian Carron[6], Manuel Izquierdo[1], Tyler Chase[4], Bruce Clemens[4], Georgi Dakovski[6], Eric Fullerton[5], Patrick Granitzka[4], Alexander Gray[3], Stefan Günther[2], Daniel Higley[4], Emmanuelle Jal[3], Loïc Le Guyader[7], Joel Li[4], Serguei Molodtsov[1], Mike Minitti[6], Ankush Mitra[6], Alexander Reid[3], William Schlotter[6], Vojtech Uhlir[5], Joachim Stöhr[3], Hermann Dürr[3], Christian Back[2], and Andreas Scherz[1] — [1]European XFEL — [2]Universität Regensburg, Germany — [3]Stanford Institute for Materials and Energy Science, USA — [4]Stanford University, USA — [5]University of California San Diego, USA — [6]Linac Coherent Light Source, Stanford, USA — [7]Helmholtz Zentrum Berlin für Materialien und Energie, Germany

FeRh undergoes a first order phase transition from antiferromagnetic (AFM) to ferromagnetic (FM) where the magnetization is the order parameter. The transition is accompanied by an isotropic lattice expansion in the bulk. The transition has been extensively studied theoretically and experimentally, in thermal equilibrium and in the time domain, but a precise understanding remains elusive. We have studied the laser-driven phase transition with time-resolved x-ray diffraction (tr-RXD) at the Linac Coherent Light Source. The experiment has revealed a number of phenomena from sub-ps magnetic transients, FM nucleation, and domain growth processes with nanometer spatial resolution and femtosecond time resolution from the electronic point-of-view of the Fe L3 edge.

MA 48.21 Thu 15:00 Poster B1

Tunable magnon-photon coupling in a compensated rare earth garnet – 3D cavity system — •Hannes Maier-Flaig[1,2], Michael Harder[3], Stefan Klingler[1,2], Zhiyong Qiu[4], Eiji Saitoh[4], Rudolf Gross[1,2], Hans Huebl[1,2], and Sebastian T.B. Goennenwein[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik - Department, Technische Universität München, Garching, Germany — [3]Department of Physics and Astronomy, University of Manitoba, Canada — [4]Institute for Materials Research, Tohoku University, Sendai, Japan

Strong spin-photon coupling is a major goal in quantum information memory applications, as it allows to coherently exchange information between the photons of a microwave cavity and a paramagnetic spin ensemble. This concept was recently transferred to magnetically ordered systems showing coupling rates of hundreds of megahertz even at room temperatures. Here, we demonstrate strong coupling of a micrometer thick $Gd_3Fe_5O_{12}$ (GIG) film and a 3D microwave cavity at distinct cryogenic temperatures. By employing a first-principles model of the coupled magnon-photon system, we reliably extract the relevant coupling parameters. The strongly temperature dependent magnetization of GIG (a compensated ferrimagnetic oxide) allows to tune the effective coupling rate of the system over a wide range, solely by changing the temperature. We are therefore able to observe the transition from a strongly coupled system to the weakly coupled regime in which ferromagnetic resonance experiments are usually performed.

MA 48.22 Thu 15:00 Poster B1

Electron dynamics driving ultrafast magnetization dynamics in itinerant ferromagnets and alloys — •Sebastian Weber and Baerbel Rethfeld — Fachbereich Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale [Beaurepaire et al., PRL 76, 4250 (1996)]. 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 [Mueller et al., NJP 13, 123010 (2011) and PRL 111, 167204 (2013)].

Recent experiments have revealed element-specific dynamics in exchange coupled ferromagnetic alloys [Mathias et al., PNAS 109, 4792 (2012)]. We set up a microscopic model to trace the electron dynamics with spin-resolution and in dependence on the material in the alloy.

MA 48.23 Thu 15:00 Poster B1

Resonant optical excitation of ultrafast magnetization dynamics in Iron Garnets by a sequence of optical pulses — •Manuel Jäckl[1], Dmitri Morosov[1], Igor V. Savochkin[2], Dmitri V. Dodonov[3], Ilya A. Akimov[1,4], Vladimir I. Belotelov[4,5], Anatoly K. Zvezdin[3,5], and Manfred Bayer[1,4] — [1]Experimentelle Physik 2, TU Dortmund, D-44221 Dortmund, Germany — [2]Lomonosov Moscow State University, 119991 Moscow, Russia — [3]Moscow Institute of Physics and Technology, Moscow Region, 141700 Russia — [4]A.F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [5]Russian Quantum Center, Skolkovo, Moscow Region, 143025 Russia

We use the inverse Faraday effect in order to influence the magnetization of a ferromagnetic bismuth iron garnet (BIG) films by means of circularly polarized femtosecond laser pulses, leading to a precession of the magnetization with a lifetime of several nanoseconds and a frequency between 2 – 7 GHz in transverse magnetic fields of 70 – 250 mT, respectively. Using a sequence of optical pulses with a repetition rate of $F_{\text{Rep}} = 1$ GHz which is larger than the decay rate of the oscillation, allows us to achieve synchronization of spin wave modes with frequencies F which satisfy the resonance condition of $F = nF_{\text{Rep}}$ (n is an integer). Consequently the amplitude of the magnetization precession increases when the modes are synchronized. Fourier sum analysis of the data and its magnetic field dependence allow to evaluate the comprehensive spectrum of spin waves in studied samples.

MA 48.24 Thu 15:00 Poster B1

Element-selective investigation of the spin dynamics in NixPd1-x magnetic alloys in the extreme ultraviolet spectral range — •Seung-gi Gang[1], Roman Adam[1], Christian Weier[1], Moritz von Witzleben[1], Moritz Plötzing[1], Oliver Schmitt[4], Henry C. Kapteyn[2], Margaret M. Murnane[2], Pablo Maldonado[3], Stefan Mathias[5], Martin Aeschlimann[4], 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 JILA, University of Colorado, Boulder, CO 80309-0440, USA — [3]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden — [4]University of Kaiserslautern and OPTIMAS, 67663 Kaiserslautern, Germany — [5]University of Göttingen, 37077 Göttingen, Germany

Optical pump-probe experiments allow the investigation of spin dynamics in magnetic materials on femtosecond time scales. Alloying 4d non-magnetic and 3d magnetic transition metals is expected to improve our understanding of the exchange interaction. We studied the ultrafast demagnetization of NixPd1-x alloys with varying x element selectively using a laser-based extreme ultraviolet light source. The spin-orbit coupling was further tuned with mixing ratio to study its influence. Transversal MOKE results measured for the Ni subsystem display an opposite quenching dependence on the stoichiometry compared to longitudinal MOKE probing the integrated response of both materials. Further experiments addressing the Pd subsystem are expected to clarify the role of the Pd, as a possible spin reservoir.

MA 48.25 Thu 15:00 Poster B1

Ultrafast Magnetostriction of Antiferromagnetic Holmium studied by Femtosecond X-ray Diffraction — •Jan-Etienne Pudell[1], Alexander von Reppert[1], Flavio Zamponi[1], Matthias Rössle[1], Daniel Schick[2], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Wilhelm-Conrad-Röntgen Campus, BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We present time-resolved X-ray diffraction on a Holmium thin film after femtosecond laser excitation. The lattice shows rich spatio-temporal dynamics, where the contraction and expansion are driven by the laser excitation. The indirect exchange interaction (RKKY) in the 80 nm Holmium film leads to an incommensurate helical antiferromagnetic (AFM) spin structure below the Néel temperature. The strong magnetostriction in Holmium results in a decrease of the lattice constant with temperature. The sub-pico to nanosecond lattice dynamics after photoexcitation are studied by ultrafast X-ray diffraction (UXRD) using a laser-driven Plasma X-ray Source (PXS). The sample is excited with an 800 nm femtosecond laser pulse at various temperatures. The phonon driven lattice expansion takes place within 15 ps and is sound velocity limited. Below the Néel temperature, the heating of the magnetic system induces an ultrafast magnetostriction, which leads to a maximal contraction within 25 ps. With a linear chain simulation the spacial and time resolved strain profile induced by the strong magnetostriction is analyzed.

MA 48.26 Thu 15:00 Poster B1

Delay- and depth-dependent simulations of the fluence-dependent magnetization dynamics in Gd — •Markus Gleich[1], Kamil Bobowski[1], Björn Frietsch[1], Niko Pontius[2], Christian Schüssler-Langeheine[2], Christoph Trabant[1], Marko Wietstruk[1], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany

We performed delay- and depth-dependent simulations of the fluence-dependent magnetization dynamics in Gd based on the microscopic three temperature model (M3TM) by Koopmans *et al.* [1]. For the calculations the M3TM was modified and extended to model the laser excitation process [2]. Our results were compared with the fluence-dependent magnetization dynamics ($1.9-11.2\,\text{mJ/cm}^2$) of a single-crystalline Gd(0001) sample measured with X-ray magnetic circular dichroism in reflection at the FEMTOSPEX facility at BESSY II. For the simulations several parameters, e.g., the thermal conductivity and the heat capacity, were varied to reproduce the measured fluence-dependent magnetization dynamics. Our simulations reproduce the two-step demagnetization qualitatively but we could not achieve the quantitative agreement previously demonstrated for nickel [3].

[1] B. Koopmans *et al.*, Nat. Mater. **9**, 259–265 (2010).
[2] Y. P. Meshcheryakov *et al.*, Appl. Phys. A **82**, 363–368 (2005).
[3] T. Roth *et al.*, Phys. Rev. X **2**, 021006 (2012).

MA 48.27 Thu 15:00 Poster B1

Ultrafast Lorentz microscopy: towards femtosecond imaging of magnetization dynamics — •Nara Rubiano da Silva[1], Marcel Möller[1], Jan Gregor Gatzmann[1], Armin Feist[1], Tim Eggebrecht[2], Ulrike Martens[3], Henning Ulrichs[2], Vladyslav Zbarsky[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 (LM) enables magnetization imaging with a spatial resolution reaching 2-20 nm [1]. Based on this technique, we have developed two approaches to address rapid magnetization processes triggered by femtosecond laser excitation. In a first approach, irreversible changes of the magnetic structure after single excitation pulses are sampled via static LM. In continuous Fe thin films on a SiN substrate, we observe the laser-induced formation of a dense vortex/antivortex network that is metastable at room temperature [2]. Furthermore, we will present first results from the implementation of a laser-pump/electron-probe scheme in a transmission electron microscope. This instrument will be capable of elucidating ultrafast spin dynamics in magnetic nanostructures using highly coherent femtosecond electron pulses.

[1] J. N. Chapman et al., J. Magn. Magn. Mater. (1999).
[2] T. Eggebrecht et al., submitted.

MA 48.28 Thu 15:00 Poster B1

Magnetization dynamics in ferromagnetic layers induced by spin-polarized current — •Muhammad Imtiaz Khan[1], Johanna Hackl[1], Slavomír Nemšák[1], Umut Parlak[1], Hatice Doğanay[1], Daniel Gottlob[3], Stefan Cramm[1], Daniel Bürgler[1], and Claus Michael Schneider[1,2] — [1]Peter Grünberg Institut 6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Fakultät für Physik and Center for Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, 47048 Duisburg, Germany — [3]CEA Saclay, 91191 Gif-sur-Yvette Cedex, France

The spin-polarized current induced magnetization dynamics is investigated by time resolved aberration-corrected photoelectron emission microscope. We explicitly measure the domain wall motion after applying each subsequent pulse in a permalloy structure. The pump-probe technique is then carried out to image the time evolution of the domain wall's magnetization by synchronizing the current pulse with the synchrotron radiation pulse train.

MA 48.29 Thu 15:00 Poster B1

Sub-monolayer film growth of volatile β-dikenonate lanthanide complexes on metallic surfaces — •Jinjie Chen[1], Hironari Issihiki[1], Kevin Edelmann[1,2], and Wulf Wulfhekel[1,2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT) — [2]Institut for Nanotechnology, Karlsruhe Institute of Technology (KIT)

We demonstrate that volatile β-dikenonate lanthanide complexes can be deposited on various metallic surfaces in ultra-high vacuum without molecule decomposition and surface contamination. The morphology of the well assembled sub-monolayer molecular films was studied by scanning tunneling microscopy at 5 K. The molecules order in commensurate structure on Cu(111), Ag(111). On Au(111), they nucleate at the elbows of the reconstruction. Delocalized molecular orbitals were found in scanning tunneling spectroscopy and spatially imaged by dI/dV maps. Our work expended the catalogue for rare earth magnetic molecules which can be studied by scanning tunneling microscopy.

MA 48.30 Thu 15:00 Poster B1

Comparing XMCD and DFT with STM spin excitation spectroscopy for Fe and Co adatoms on Cu_2N/Cu(100) — •Markus Etzkorn[1,2], Cyrus F. Hirjibehedin[3], Anne Lehnert[1], Safia Ouazi[1], Stefano. Rusponi[1], Sebastian Stepanow[4], Pietro Gambardella[4], Carsten Tieg[5], Pardeep Thakur[5], Alexander I. Lichtenstein[6], Alexander B. Shick[7], Sebastian Loth[8], Andreas Heinrich[9], and Harald Brune[1] — [1]EPFL, Lausanne, Switzerland — [2]MPI for Solid State Research, Stuttgart, Germany — [3]London Centre for Nanotechnology, UCL, United Kingdom — [4]ETH Zürich, Zürich, Switzerland — [5]ESRF, Grenoble, France — [6]University of Hamburg, Hamburg, Germany — [7]Institute of Physics, Prague, Czech Rep. — [8]CFEL, Hamburg, Germany — [9]IBM Almaden Research Center, San Jose, USA

We compare the magnetic properties of ensembles of single Fe and Co atoms on a Cu_2N monolayer on Cu(100) deduced from x-ray circular magnetic dichroism (XMCD) and density functional (DFT) calculations with spin excitation spectroscopy (SES) measurements on single atoms [1]. We focus in particular on the values of the local magnetic moments determined by XMCD compared to the expectation values derived from the spin Hamiltonian used to describe the SES data. Within this model we are able to understand the angular dependence of the projected magnetic moments along the magnetic field, as measured by XMCD. In agreement with DFT, the XMCD measurements show large orbital contributions to the total magnetic moment for both magnetic adatoms. [1] M.Etzkorn *et al.*, PRB 92 (2015) 184406.

MA 48.31 Thu 15:00 Poster B1

First-principles study of magnetism in FeIr bilayers on Rh(001) — •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, complex non-collinear spin structures such as spin spirals, spin lattices or skyrmions have been discovered at transition-metal surfaces [1-3]. In particular, the magnetic ground state of Fe monolayers can be tuned at interfaces with other 4*d* and 5*d* transition-metals [4]. Here, we use density functional theory as implemented in the full-potential linearized augmented plane wave method to investigate the magnetic properties of bilayers from Fe and Ir on the Rh(001) surface. We consider both ways of growing the bilayer on the substrate, i.e. Fe/Ir/Rh(001) and Ir/Fe/Rh(001). Both systems are structurally relaxed and the magnetic ground state is determined by total energy calculations. We compare the ferro- and antiferromagnetic state of the Fe monolayer and find a significant influence of the stacking sequence of the bilayer. The calculated energy dispersion of spin spirals provides evidence for a non-collinear ground state.

[1] S. Heinze *et al.*, Nature Phys. **7**, 713 (2011).
[2] M. Hoffmann *et al.*, Phys. Rev. B **92**, 020401(R) (2015).
[3] N. Romming *et al.*, Science **341**, 636 (2013).
[4] B. Hardrat *et al.*, Phys. Rev. B **79**, 094411 (2009).

MA 48.32 Thu 15:00 Poster B1

Magnetic linear dichroism of 3d metal thin films — •Torsten Veltum[1], Tobias Löffler[1], Mathias Gehlmann[2], Sven Döring[2], Lukasz Plucinski[2], 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

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. Because we are interested in a deeper understanding of the magnetic linear dichroism of 3d metals, we study epitaxially grown Co(0001) and Fe(110) 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 the experimental data. At the beamline we have access to angle-resolved photoemission spectroscopy and low energy electron diffraction.

The electronic structure of the valence band is measured by variation of the photon energy. At excitation energies above 20 eV, dichroism measurements are reconfirmed and extended to angle-resolved spectra in off-normal geometry. The resonance between the 3d core-levels and the valence band of these materials shows an influence on the dichroism.

MA 48.33 Thu 15:00 Poster B1

towards ferromagnetic resonance in scanning tunneling microscopy using homodyne detection — •marie hervé, moritz peter, and wulf wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

In this communication we report on the experimental development of a new technique to measure locally ferromagnetic resonance signals with a SP-STM. The concept of this experiment, inspired by the spin torque diode effect [1], is based on the homodyne detection of the resonance signal in the sample. A continuous radio-frequency (rf) voltage (up to 3 GHz) is mixed to the bias voltage of the STM. If there is a magnetisation precession under the STM tip, the tunneling conductance will be modulated at the resonance frequency. When the high frequency signal mixed to the tunneling junction reach the resonance frequency of the precession, the tunneling current is rectified. This rectified current, measurable by conventional STM transimpedance amplifier correspond to a ferromagnetic resonance signal in the sample.

[1] 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)

MA 48.34 Thu 15:00 Poster B1

Spin wave propagation in anisotropic monocrystalline iron stripes — •Helmut Körner, Johannes Stigloher, Matthias Kronseder, and Christian Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

Pure iron might be a suitable candidate for spin wave based applications due to its promising properties such as low damping factor, high saturation magnetization and well-defined magneto-crystalline anisotropy, calling for profound investigations of spin wave propagation in this material. Our sample is a Fe(10 nm)/AlOx(5 nm) full film grown on top of a GaAs substrate by means of molecular beam epitaxy showing a pre-dominant cubic magneto-crystalline anisotropy which is then patterned into micrometer-sized stripes with different orientations with respect to the crystallographic axes of the iron. In these stripes, we study the propagation of electrically excited magnetostatic Damon-Eshbach spin waves employing time-resolved scanning Kerr microscopy in combination with micromagnetic simulations using the GPU-accelerated simulation program mumax^3.

MA 48.35 Thu 15:00 Poster B1

Electrically detected FMR in the field-polarized phase of Cu_2OSeO_3 — •Stefan Weichselbaumer[1,2], Ioannis Stasinopoulos[1], Andreas Bauer[3], Helmuth Berger[4], Johannes Waizner[5], Markus Garst[5], Christian Pfleiderer[3], and Dirk Grundler[1,6] — [1]Physik-Department E10, TU München, Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [3]Physik-Department, FG Magnetische Materialien, TU München, Garching, Germany — [4]EPFL, Institut de physique de la matiere complexe, Lausanne, Switzerland — [5]Institute for Theoretical Physics, Univ. Köln, Köln, Germany — [6]LMGN, IMX, EPFL, Lausanne, Switzerland

The insulating chiral magnet Cu_2OSeO_3 recently gained a lot of interest as it exhibits a Skyrmion lattice and spin helix phase. The insulating nature of this material as well as the magnetoelectric coupling could lead to efficient spin-based devices. We investigate collective excitations in the field-polarized ferrimagnetic phase of Cu_2OSeO_3 using a broadband spectroscopy setup based on a vector network analyzer. By evaporating a thin Pt layer on our sample and measuring the voltage across the Pt stripe, we are able to electrically detect the ferromagnetic resonance (FMR) signal. We observe a significant influence of heating effects due to microwave irradiation. Our analysis shows that several effects contribute to the signal, including the spin rectification effect (SR) and spin pumping (SP). Financial support by the DFG via TRR80 is acknowledged.

MA 48.36 Thu 15:00 Poster B1

Broadband spin-wave spectroscopy on a nanostructured ferrimagnetic thin film — •Stefan Mändl[1], Florian Heimbach[1], Stefan Weichselbaumer[2], and Dirk Grundler[3] — [1]Physik Department E10, TU München, Garching, Germany — [2]Walther Meißner Institut, TU München, Garching, Germany — [3]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. It was found that the reciprocal-lattice vector provided by a periodic magnetic modulation in a metallic thin film adds to the wave vector of a Damon-Eshbach mode [1]. In our work, we explore 200 nm thick yttrium iron garnet (YIG) produced by liquid phase epitaxy by broadband spin-wave spectroscopy and excite spin waves using coplanar waveguides. We investigate spin waves induced in the unpatterned and periodically modulated YIG film containing a two-dimensional lattice of nanotroughs etched by argon ion milling. We compare our results with spin waves reported for a 20 nm thick ferrimagnetic YIG film produced by pulsed laser deposition [2]. The work is supported by the DFG via GR1640/5 in SPP 1538 and NIM.

[1] H. Yu et al., Nat. Commun. 4, 2702 (2013)
[2] H. Yu et al., Scientific Reports 4, 6848 (2014)

MA 48.37 Thu 15:00 Poster B1

Coplanar waveguide based ferromagnetic resonance in thin magnetic films: influence of a superconducting layer — •Philip D. Louis[1,2], Matthias Althammer[2], Hannes Maier-Flaig[1,2], Mathias Weiler[1,2], Hans Huebl[1,2,3], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,2,3] — [1]Physik-Department, Technische Universität München, Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), München, Germany

The high-frequency properties of magnetic materials are of general interest from both an application and a fundamental research point of view. Coplanar waveguide (CPW) based ferromagnetic resonance (FMR) allows for a broadband spectroscopy of magnetization dynamics. In order to maximise the FMR signal and enhance sensitivity, it is important to efficiently drive magnetisation dynamics via a CPW. In our experiment, we study the FMR response of cobalt/niobium thin film heterostructures at temperatures above and below the Nb superconducting phase transition temperature. The sample is mounted Co-side down on a CPW and the complex transmission S_{21} is measured using vector network analysis. We observe an amplitude increase of the Co FMR signal by up to an order of magnitude when the Nb is in its superconducting state. This result can be explained by an efficient confinement of the FMR driving field between the superconducting Nb and the CPW. This effect can be used to increase the FMR signal of ultra thin/weakly magnetic films and has to be accounted for when including superconducting films into functional multi-layers.

MA 48.38 Thu 15:00 Poster B1

Effect of Novel Exchange-Coupling Torque and Spin-Orbit Interaction on Current Induced Domain Wall Motion in Magnetic Nanowires — •Robin Bläsing[1,2], See-Hun Yang[2], Gernot Güntherodt[1,3], and Stuart S. P. Parkin[1,2] — [1]Max Planck Institute for Microstructure Physics, Halle (Saale), D-006120, Germany — [2]IBM Almaden Research Center, San Jose, California 95120, USA — [3]2nd Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany

Recent discoveries in the field of current induced domain wall motion open new possibilities for novel memory devices like the racetrack memory. Due to a large perpendicular magnetic anisotropy, the magnetization of an ultra-thin magnetic Co/Ni layer is pointing out-of-plane. In combination with the Dzyaloshinskii-Moriya interaction, Néel domain walls are formed which can be driven by a spin Hall current induced e.g. by an adjacent Pt underlayer, resulting in a domain wall velocity of about 400 m/s. In this work, a further improvement is achieved with synthetic antiferromagnetic structures, where two ultrathin ferromagnetic layers are coupled antiparallel via the Ruderman-Kittel-Kasuya-Yosida exchange interaction. This exchange coupling gives rise to a novel exchange-coupling torque which increases the domain wall velocity up to 750 m/s.

MA 48.39 Thu 15:00 Poster B1

Spin-torque measurements in NiFe/Pt bilayers with different Pt thickness — •Robert Islinger, Martin Decker, and Martin Obstbaum — Institute for Experimental and Applied Physics, University Regensburg, 93040 Regensburg, Germany

Spin-torque ferromagnetic resonance (ST-FMR) is a reliable method to determine the spin Hall angle in ferromagnetic/normal metal bilayers [1]. In this study we use NiFe/Pt bilayers with varying Pt thickness in order to extract the spin diffusion length and the spin Hall angle. We explain this method in detail and compare the values with modulation of damping and inverse spin Hall effect measurements.

[1] Liu et al. PRL 106, 036601 (2011)

MA 48.40 Thu 15:00 Poster B1

Time Resolved Scanning Tunnelling Spectroscopy on Magnetic Vortex Cores — Christian Saunus, •Marco Pratzer, Lukas Deutz, and Markus Morgenstern — II. Physikalisches Institut B, RWTH Aachen University and JARA-FIT, 52074 Aachen, Germany

A magnetic vortex is the simplest non-trivial magnetic order showing up in a magnetic disk with no magnetic anisotropy. The centre of this chiral magnetic structure features an out of plane magnetic moment called the vortex core. The vortex core can be driven to a resonant gyration by radio-frequency magnetic fields or spin polarized currents [1,2].

We performed spin polarized scanning tunnelling spectroscopy on Fe nano islands prepared on a W(110) crystal. The magnetic vortices are mapped using an anti-ferromagnetic tip made of bulk chromium. In order to excite the gyro mode we superimpose the bias voltage of the STM with a tunable high frequency voltage up to 3 GHz. We measure the resulting dc current as a function of frequency, which is interpreted in terms of the gyro mode.

[1] S.-B. Choe et al., Science 304, 420 (2004).
[2] S. Kasai et al., Phys. Rev. Lett. 97, 107204 (2006).

MA 48.41 Thu 15:00 Poster B1

Twofold and fourfold symmetric anisotropic magnetoresistance effect in a model with crystal field — •Satoshi Kokado[1] and Masakiyo Tsunoda[2] — [1]Shizuoka University, Hamamatsu, Japan — [2]Tohoku University, Sendai, Japan

We theoretically study the twofold and fourfold symmetric anisotropic magnetoresistance (AMR) effect [1]. We first extend our previous model [2, 3] to a model including the crystal field effect [1]. Using the model, we next obtain an analytical expression of the AMR ratio, i.e., AMR(ϕ)=$C_0 + C_2\cos(2\phi) + C_4\cos(4\phi)$, with C_0=$C_2 - C_4$ [1]. Here, ϕ is the relative angle between the magnetization direction and the electric current direction and C_2 (C_4) is a coefficient of the twofold (fourfold) symmetric term. The coefficients C_2 and C_4 are expressed by a spin-orbit coupling constant, an exchange field, a crystal field, and s-s and s-d scattering resistivities. Using this expression, we analyze the experimental results for Fe_4N [4, 5], in which $|C_2|$ and $|C_4|$ increase with decreasing temperature. The experimental results can be reproduced by assuming that the tetragonal distortion increases with decreasing temperature.

[1] S. Kokado *et al.*, J. Phys. Soc. Jpn. **84**, 094710 (2015).
[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] M. Tsunoda *et al.*, Appl. Phys. Express **3**, 113003 (2010).
[5] K. Kabara *et al.*, Appl. Phys. Express **7**, 063003 (2014).

MA 48.42 Thu 15:00 Poster B1

Domain wall motion in a ferromagnet induced by pure diffusive spin currents in graphene — •Fabienne Musseau[1], Michele Voto[2], Alexander Pfeiffer[1], Nils Richter[1], Luis Lopez Diaz[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Departamento de Física Aplicada, Universidad de Salamanca, 37008 Salamanca, Spain

Due to the miniaturization of systems to the nanoscale, the physics of surfaces and interfaces is a major area of research. The controlled motion of magnetic domain walls is a vital component of various spintronic devices and memory applications, such as the racetrack memory which uses spin currents [1]. Another possibility is to use pure diffusive spin currents to manipulate the magnetization in a ferromagnet at very low spin current densities [2,3]. In our measurements, the non-local spin valves consists of two permalloy half rings which are connected via a non-magnetic graphene spin conduit, a geometry which permits the precise positioning of domain walls. We choose graphene due to its low spin-orbit coupling and large spin diffusion length, allowing for the propagation of spin currents with little attenuation [4]. We investigated the displacement of domain walls via spin torques exerted by pure diffusive spin currents in the non-local spin valve geometry [2,3]. We compare our results to micromagnetic simulations to understand the acting torques. [1] S. S. P. Parkin et al., Science 320, 190 (2008), [2] N. Motzko et al., Phys. Rev. B, 88, 214405 (2013), [3] D. Ilgaz et al., Phys. Rev. Lett. 105, 076601 (2010), [4] N. Tombros et al., Nature 448, 571 (2007)

MA 48.43 Thu 15:00 Poster B1

Mg diffusion in Fe_3O_4 based magnetic tunnel junctions with MgO barrier — •Luca Marnitz[1], Tobias Peters[1], Denis Dyck[1], Jari Rodewald[2], Olga Kuschel[2], Joachim Wollschläger[2], Stephan Wallek[2], Karsten Rott[1], Jan-Michael Schmalhorst[1], Thorsten Glaser[2], Günter Reiss[1], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]Universität Osnabrück, Germany

Due to its high spin polarization and Curie temperature, magnetite (Fe_3O_4) is a promising material for room temperature applications in spintronics and spincalorics. In a previous publication, a sign change in the tunneling magnetoresistance of CoFeB/MgO/Fe_3O_4/MgO(001) magnetic tunnel junctions was observed after annealing at temperatures above 240°C [1]. Mg diffusion from the MgO through the Fe_3O_4 is a possible explanation for this behaviour [2]. Further studies, including Sputter-Auger-Spectroscopy and X-ray Reflectivity have been undertaken to investigate this effect. Additionally, low temperature SQUID and Raman Spectroscopy measurements have been performed to characterise the magnetite samples.

[1] L. Marnitz et al., AIP Adv. 5, 047103 (2015)
[2] K. A. Shaw et al., J. Appl. Phys. 81, 5176 (1997)

MA 48.44 Thu 15:00 Poster B1

Side-jump contribution to the spin Hall effect within a phase shift model — •Christian Herschbach[1], Dmitry Fedorov[2,1], Martin Gradhand[3], Kristina Chadova[4], Diemo Ködderitzsch[4], Hubert Ebert[4], 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 — [4]Ludwig-Maximilians University, Munich, Germany

A precise theoretical description of the spin Hall effect (SHE) requires exhaustive and demanding *ab initio* calculations by means of relativistic codes. For a simplified description of the skew-scattering contribution to the SHE, several model approaches employing the scattering phase shifts were developed [1-5]. A corresponding resonant scattering model for the side-jump mechanism was proposed [3] as well.
Here, we present a generalized phase shift model for the description of side-jump. Its validity is studied in comparison to *ab initio* calculations performed within the Kubo-Středa approach [6]. Furthermore, we discuss the results in the light of the simplified approximation of Ref. [3]. It is shown that the model's restriction to impurity properties cannot reproduce the results of first-principles calculations, which, therefore, seem to be inevitable for reliable predictions.

[1] Fert *et al.*, JMMM **24**, 231 (1981); [2] Guo *et al.*, PRL **102**, 036401 (2009); [3] Fert and Levy, PRL **106**, 157208 (2011); [4] Fedorov *et al.*, PRB **88**, 085116 (2013); [5] Herschbach *et al.*, PRB **88**, 205102 (2013); [6] Chadova *et al.*, PRB **92**, 045120 (2015).

MA 48.45 Thu 15:00 Poster B1

Spin-Transfer-Torque in Magnetic Tunnel Junctions — •Christian Denker[1], Jakob Walowski[1], Ulrike Martens[1], Vladislav Zbarksi[2], Günter Reiss[3], and Markus Münzenberg[1] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität, Greifswald, Germany — [2]Fakultät für Physik, Georg-August Universität, Göttingen, Germany — [3]CSMD, Physics Department, Universität Bielefeld, Germany

Magnetic tunnel junctions based on MgO symmetry filtering allow specific control of the electronic structure and are appealing for THz spintronics.

Our optimized MgO/CoFeB based layer stack with perpendicular tunnel junction shows a minimal critical switching of only 9.3 kA/cm^2. This is partly associated with a thermally activated switching probability and specific switching distribution [1]. We found the enhanced demagnetization observed by He et al. [2] and a distinct selection of electrons tunneling through the MgO barrier by switching parallel and antiparallel magnetization for varied anisotropy values along a wedge sample in pump-probe spectroscopy with fs excitation. We show that different effects on time scales related to energy-momentum distribution of hot electrons, which relax within 70 fs, determine the THz currents in samples with barrier thickness of only 2 monolayers MgO. This will eventually allow a spin transfer of the hot electrons into the second CoFeB layer even on a ps time scale.

[1] Leutenantsmeyer et al., Mater. Trans., 9, 56 (2015)
[2] He et al. Sci. Rep. 3, 2883 (2013)

MA 48.46 Thu 15:00 Poster B1

Preparation and characterization of beta-W thin films for spin Hall effect experiments — •Timo Oberbiermann[1], Christoph Klewe[1], Jari Rodewald[2], Olga Kuschel[2], Joachim Wollschläger[2], Günter Reiss[1], and Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Fachbereich Physik, Universität Osnabrück, Germany

Recently, the spin Hall effect in metals, more precisely in Pt and β W, was detected optically by magnetooptical Kerr effect (MOKE) measurements [1]. However, the physical properties of tungsten thin films are strongly affected by the film microstructure. While the thermodynamically stable α phase exhibits no detectable spin Hall effect, the metastable β phase shows a large spin Hall angle α_{SH} of 0.33 [2]. Hence, it is important to find appropriate conditions to prepare W films for spincaloric applications.

In this work, different W thin films were fabricated using magnetron sputtering. Process preassure, deposition time and sputtering power were varied to evaluate the ideal deposition parameters. The samples were characterized by x-ray diffraction and x-ray reflectometry to determine their structures and interface properties.

Additionally, the temporal stability of the W β phase was investigated and optical spin Hall measurements were performed, both via MOKE and x-ray resonant magnetic reflectivity (XRMR).

[1] O.M.J. Van t'Erve et al., Appl. Phys. Lett. 104, 172402 (2014)
[2] C.-F. Pai et al., Appl. Phys. Lett. 101, 122404 (2012)

MA 48.47 Thu 15:00 Poster B1

Non-local magnetoresistance in YIG/Pt nanostructures — •Tobias Wimmer[1,2], Sebastian Goennenwein[1,2,3], Kathrin Ganzhorn[1,2], Richard Schlitz[1,2], Matthias Pernpeintner[1,2,3], Matthias Althammer[1], Rudolf Gross[1,2,3], and Hans Huebl[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 (NIM), Schellingstraße 4, 80799 München Germany

The spin Hall magnetoresistance (SMR) in ferrimagnetic insulator/normal metal heterostructures has been extensively studied in Yttrium Iron Garnet /Platinum (YIG/Pt) bilayer structures. Recently, a non-local analogue of the SMR has been discovered in YIG/Pt nanostructures with two parallel Pt strips separated by a few 100 nm. Owing to the spin Hall effect, a charge current flowing along one Pt strip will generate a transverse spin current. The latter can create or annihilate magnons in the ferrimagnet, depending on magnetization orientation. As a result, an electrically generated non-equilibrium magnon population diffuses within the ferrimagnet, generating a non-local voltage drop across the second Pt strip. We investigate the evolution of this non-local magnon mediated magnetoresistance with temperature, magnetic field strength and field orientation. Our results show that the mechanisms behind the spin Hall and the non-local magnetoresistance are qualitatively different.

MA 48.48 Thu 15:00 Poster B1

Spin Hall magnetoresistance in erbium iron garnet — •Hiroto Sakimura[1], Michaela Lammel[1], Matthias Althammer[1], Stephan Geprägs[1], Rudolf Gross[1,2], and Sebastian T. B. Goennenwein[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Fakultät für Physik, Technische Universität München, Garching, Germany

The interconversion of spin and charge currents via the (inverse) spin Hall effect in normal metal (NM)/ferromagnetic insulator (FMI) bilayers leads to the spin Hall magnetoresistance (SMR). The SMR manifests itself in the dependence of the electrical resistivity of the NM layer on the magnetization orientation of the FMI. By using erbium iron garnet ($Er_3Fe_5O_{12}$, ErIG) as the ferrimagnetic insulator with a magnetic compensation point at 78 K, further insight on the dependence of the SMR on the sub-lattice magnetizations can be obtained. Here we report on the fabrication of ErIG/Pt bilayers on (100)-oriented $Gd_3Fe_5O_{12}$ and $Y_3Al_5O_{12}$ substrates by pulsed laser deposition and subsequent electron beam evaporation. High crystalline quallity of our thin films is confirmed by X-ray diffraction measurement. The compensation temperatures of the thin films observed by SQUID magnetometry were close to the bulk value. The temperature dependence of the SMR in these ErIG/Pt bilayers shows a decrease of the SMR amplitude at the compensation point, suggesting a complex interplay of the different magnetic sub-lattices for the SMR. - This work is supported by the DFG via SPP 1538.

MA 48.49 Thu 15:00 Poster B1

Spin Hall effect in the non-collinear antiferromagnets $IrMn_3$ and $PtMn_3$ — •James Taylor[1], Yong Pu[1], Jue Huang[1], Weifeng Zhang[2], Wei Han[2], See-Hun Yang[2], Claudia Felser[3], and Stuart S.P. Parkin[1,2] — [1]Max Planck Institute for Microstructure Physics, D-06120 Halle, Germany — [2]IBM Almaden Research Center, San Jose, California 95120, USA — [3]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Recent work has demonstrated a large spin Hall effect (SHE) in antiferromagnets (AFM); including the ability to tune SHE by changing the crystal structure, and hence internal AFM ordering, of the materials. The triangular arrangement of magnetic moments in a non-collinear AFM is associated with a chirality, which is predicted to give rise to a significant anomalous Hall effect. With both effects sharing a common origin in spin-orbit coupling, such chiral spin textures may also give rise to large SHE. In this work, we report progress towards measurement of the spin Hall angle (SHA) in the non-collinear AFMs $IrMn_3$ and $PtMn_3$. SHA was measured using the spin-torque ferromagnetic resonance technique, in AFM/Py (= $Ni_{81}Fe_{19}$) bilayers. Initial results show a facet dependence of the SHA (θ_{SH}) measured in $IrMn_3$. In (100) oriented $IrMn_3$, $\theta_{SH} = 0.2$, but in the (111) orientation $\theta_{SH} = 0.12$. Further measurements will extend to $PtMn_3$, which has been grown using DC magnetron sputtering, with composition confirmed by Rutherford back scattering and crystal structure investigated using X-ray diffraction. In future work we aim to elucidate the effect of chiral magnetic ordering on measured SHA.

MA 48.50 Thu 15:00 Poster B1

Dependence of the temporal dynamics of the longitudinal spin Seebeck effect on the magnetic layer thickness in YIG/Pt bilayers — •Timo Noack, Thomas Langner, Frank Heussner, Viktor Lauer, Alexander Serga, Burkard Hillebrands, and Vitaliy Vasyuchka — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany

The longitudinal spin Seebeck effect (LSSE) attracts a rising interest for both fundamental studies and application developments. The spectral properties of the LSSE are not completely understood so far. Our main focus was to investigate the temporal dynamics of the LSSE with focus on the dependence of the transition processes on the thickness of a magnetic film (in our case yttrium-iron-garnet, YIG) (0.27μm-50μm) in YIG/Pt bilayers. To obtain spectral properties of the LSSE a time resolved measurement technique with single pulsed microwave-induced heating, as well as a frequency resolved measurement technique with amplitude modulated heating were utilized. Both experiments show that the temporal dynamics of the LSSE becomes slower with increase of the YIG thickness. Specifically, with decrease of the YIG film thickness single-pulse measurements result in an decrease in the LSSE rise-time, while the frequency modulation method results in an increase of the cut-off frequencies (-3dB of initial LSSE voltage at 1kHz). This behavior evidences the significant contribution of bulk magnon modes to the LSSE. Financial support by the Deutsche Forschungsgemeinschaft within Priority Program 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 48.51 Thu 15:00 Poster B1

Dependence of transverse magneto-thermoelectric effects on inhomogeneous magnetic fields — •Anatoly Shestakov[1], Maximilian Schmid[1], Daniel Meier[2], Timo Kuschel[2], and Christian Back[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, 33615 Bielefeld, Germany

Transverse magneto-thermoelectric effects, namely Anomalous Nernst Effect (ANE), Anisotropic magneto-thermopower (AMTEP, also known as Planar Nernst effect) and transverse spin Seebeck effect (TSSE), are studied in Permalloy thin films grown on MgO substrates. For the detection of spin-currents Pt strips on top of the Permalloy films are used. We find that small static parasitic magnetic fields below 1 Oe can produce TSSE-like signals of the order of 1% of the amplitude of the AMTEP. The measured artifacts reveal a new source of uncertainties for the detection of the TSSE in conductive ferromagnets. Taking these results into account we conclude that the contribution of the TSSE to the detected voltages is below the noise level of 20 nV.

MA 48.52 Thu 15:00 Poster B1

Investigation of thermal spin transfer torque in MgO-based magnetic tunnel junctions using FMR microresonators — •Hamza Cansever[1,2], Ewa Kowalska[1,2], Ciaran Fowley[1], Yuriy Aleksandrov[1,2], Oguz Yildirim[1], Rysard Narkowicz[1], Kilian Lenz[1], Jürgen Lindner[1], Jürgen Fassbender[1], 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 Dresden, Institute of Solid State Physics, 01069 Dresden, Germany

MgO-based magnetic tunnel junctions are commonly used in spintronic device applications, such as recent spin transfer torque random access memory (STT-RAM) because of their non-volatility, fast switching and high storage capacity. Spin transfer torque is defined as a spin polarized current flowing through a ferromagnet exerting a torque on the local magnetization. With thermal spin transfer torque (T-STT), thermally excited electron transport is used instead of spin polarized charge current and provides an interesting way of using thermoelectric effects in magnetic storage applications. Our study focuses on fundamental experimental research aimed at demonstrating that thermal gradients can generate spin-transfer torques in MgO-based magnetic tunnel junctions (MTJs). We use microresonators 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 gradient across the barrier. This work is supported by DFG-SPP 1538.

MA 48.53 Thu 15:00 Poster B1

Field induced suppression of the spin Seebeck effect — •Christoph Schneider[1], Joel Cramer[1], Andreas Kehlberger[1], Er-Jia Guo[1,2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Quantum Condensed Materials Division, Oak Ridge National Laboratory, TN 37830, Oak Ridge, USA

By means of the spin Seebeck effect (SSE) pure spin currents can be generated in magnetic insulators when applying temperature gradients. Recent results have shown that this spin current can be identified as thermally generated magnons from the bulk of the ferromagnetic material [1]. We present magnetic field dependent measurements of the spin Seebeck effect at room and cryogenic temperatures [2]. At increased magnetic fields a suppression of the SSE signal is observed. On account of an opening frequency gap low energy magnons, which exhibit the longest propagation lengths, are cut off and thus the overall magnon propagation length is reduced [3]. This phenomenon is predicted not only to be observed in high magnetic fields but also in materials with high anisotropy. For this we use cobalt ferrite (CFO), which as a spinel ferrite allows to modify the anisotropy by tensile strain [4] and we study the spin Seebeck effect in this material. [1] A. Kehlberger et al. Phys. Rev. Lett. 115, 096602 (2015) [2] Er-Jia Guo et al. arXiv: 1506.06037 (2015) [3] U. Ritzmann et al. Phys. Rev. B 92, 174411 (2015) [4] Er-Jia Guo et al. arXiv: 1509.03601 (2015)

MA 48.54 Thu 15:00 Poster B1

Detection of DC currents and resistance measurements in longitudinal spin Seebeck effect experiments on Pt/YIG and Pt/NFO — •Daniel Meier[1], Timo Kuschel[1], Sibylle Meyer[2], Sebastian T. B. Goennenwein[2], Liming Shen[3], Arunava Gupta[3], Jan-Michael Schmalhorst[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Walther-Meißner-Institut, BAdW, Germany — [3]MINT Center, University of Alabama, USA

In this work we investigated thin films of the ferrimagnetic insulators $Y_3Fe_5O_{12}$ and $NiFe_2O_4$ capped with thin Pt layers in terms of the longitudinal spin Seebeck effect (LSSE). The electric response detected in the Pt layer under an out-of-plane temperature gradient can be interpreted as a pure spin current converted into a charge current via the inverse spin Hall effect. Typically, the transverse voltage is the quantity investigated in LSSE measurements (in the range of μV). Here, we present the directly detected DC current (in the range of nA) as an alternative quantity. Furthermore, we investigate the resistance of the Pt layer in the LSSE configuration. We observe an influence of the test current on the resistance by the spin Hall magnetoresistance effect. The typical shape of the LSSE curve varies for increasing test currents.

MA 48.55 Thu 15:00 Poster B1

Critical Point in Antiferromagnetic Chromium Under Uniaxial Pressure — •Alexander Schade, Robert Georgii, Tim Adams, Alfonso Chacon, and Peter Böni — Technische Universität München

The weakly first order character of the Néel transition in chromium has not yet been conclusively explained. Chromium exhibits an incommensurable spin density wave, which is stabilized by the nesting of its Fermi surface. Zvi Barak et al. [1] interpret the Néel transition of chromium as fluctuation induced first order transition, and predict the existence of a critical point in a temperature over uniaxial pressure phase diagram for pressure along the 110-direction. We report elastic neutron scattering experiments with uniaxial pressure along the 110-axis, performed at MIRA, MLZ [2]. The Néel transition remains first order for pressures up to 600 bar. For higher pressures, an irreversible broadening of the Néel transition was observed, which we show is compatible with a model of plastic deformation, leaving behind residual stresses. The existence of a critical point can be ruled out in the pressure range 0-600 bar.

[1] Effect of uniaxial stress on the first-order Neel transition in chromium, Zvi Barak and M. B. Walker, J. Phys. F: Met. Phys., 12(1982)483-95.

[2] MIRA: Dual wavelength band instrument, Robert Georgii, Klaus Seemann, Journal of large-scale research facilities JLSRF, Vol 1 (2015)

MA 48.56 Thu 15:00 Poster B1

X-Ray Magnetic Circular Dichroism Measurements in doped Gadolinium Iron Garnet — •Kathrin Ganzhorn[1,2], Stephan Gepraegs[1], Matthias Opel[1], Andre Rogalev[3], Fabrice Wilhelm[3], Katharina Ollefs[3,4], Francois Guillou[3], Rudolf Gross[1,2,5], and Sebastian T. B. Goennenwein[1,2,5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]European Synchrotron Radiation Facility (ESRF), 38043 Grenoble Cedex 9, France — [4]Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany — [5]Nanosystems Initiative Munich (NIM), 80799 München Germany

Magnetically compensated rare earth garnets, such as Gadolinium Iron Garnet ($Gd_3Fe_5O_{12}$, GdIG), exhibit a pronounced temperature and magnetic field dependence of the sublattice magnetizations. In particular, the Fe and Gd sublattices can switch from a collinear to a canted configuration, resulting in a complex magnetic phase diagram. In order to determine the sublattice magnetization orientations in GdIG thin films, we performed x-ray magnetic circular dichroism (XMCD) on the Gd-L3 and Fe-K edge as a function of temperature and magnetic field. We compare the magnetic phase diagram obtained from these measurements with calculations based on a mean field model and find good agreement.

Financial support by DFG via SPP 1538 is gratefully acknowledged.

MA 48.57 Thu 15:00 Poster B1

Thermal expansion and magnetostriction studies on R_2PdSi_3(R = Ho, Dy) single crystals — •Binh Tran[1], Wolfgang Löser[2], Chongde Cao[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics, Heidelberg University, INF 227, 69120 Heidelberg, Germany — [2]Leibniz Institute for Solid State and Materials Research IFW Dresden, Helmholtzstr.20, 01069 Dresden, Germany — [3]Department of Applied Physics, Northwestern Polytechnical University, Xian 710072, P.R. China

The magnetic behavior of hexagonal R_2PdSi_3 (R = Ho, Dy) single crystals has been studied by means of capacitance dilatometry. The materials show antiferromagnetic order below $T_N = 7.9$ K (R = Ho) resp. $T_N = 7.5$ K (R = Dy) as indicated by pronounced anomalies in the uniaxial thermal expansion coefficients α_a and α_c. In addition, the data imply significant length changes well above T_N which are interpreted in terms of evolution of short range magnetic order. The application of an external magnetic field along the easy-axis leads to a transition from the antiferromagnetic order into a ferrimagnetic order. Magnetostriction measurements below T_N reveal further metamagnetic transitions which will be used to determine and to discuss the magnetic phase diagram.

MA 48.58 Thu 15:00 Poster B1

Polaronic Microstructure in Manganites — •Sangeeta Rajpurohit[1] and Peter Blöchl[1,2] — [1]Institute of Theoretical Physics, Clausthal Institute of Technology — [2]Institute of Material Physics, University of Göttingen

Mixed-valence manganites exhibit interesting transport properties because of their complex interplay between charge, orbital, lattice and spin degrees of freedom. Strong electron-phonon coupling due to Jahn-Teller distortion localizes the electrons in the e_g states as polarons. These polarons dictate the charge transport, structural and magnetic ordering properties of manganites. We investigate the dynamics on long length and time scales with Car-Parrinello molecular dynamics for a model Hamiltonian. The model Hamiltonian takes into account the electrons in the $e_g$orbitals of Mn, the classical spin of the t_{2g} electrons on Mn and the cooperative Jahn-Teller distortions of the oxygen octahedra. The electrons are treated as two-component spinors, allowing for non-collinear spin arrangements. So far, we have explored the complex phase diagram of one-dimensional model and three-dimensional manganites as function of the model parameters and doping. We observe dimer and trimer phases for different doping. We investigate the charge transport across the hetero interface of different polaronic behaviour. The parameters used in the model are extracted from Density Functional Theory using hybrid functionals.Financial support by the DFG Collaborative Research Center 1073 "Atomic scale control of energy conversion", project B03 is gratefully acknowledged.

MA 48.59 Thu 15:00 Poster B1

Hidden Symmetries in the Spin Molecules $MgCr_2O_4$, $ZnCr_2O_4$, and $CdCr_2O_4$ — •Mamoun Hemmida[1], Hans-Albrecht Krug von Nidda[1], Vladimir Tsurkan[1,2], and Alois Loidl[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, Germany — [2]Institute of Applied Physics, Academy of Sciences of Moldova, Republic of Moldova

The spin dynamics of frustrated antiferromagnetic (AFM) chromium spinel oxides XCr_2O_4 (X: Mg, Zn, Cd) is investigated by means of Electron Spin Resonance (ESR) spectroscopy. From the temperature dependent ESR linewidth, an unconventional spin-relaxation behaviour is observed. Similar to the two-dimensional triangular lattice AFMs

$ACrO_2$ (A: H, Li, Na, Cu, Ag, Pd), direct spin-spin interactions are dominant. A Berezinskii-Kosterlitz-Thouless-like (BKT) scenario successfully describes the linewidth in the whole paramagnetic Regime.[1,2] In order to describe the spin-relaxation via vortex-like excitations in XCr_2O_4 compounds, generalized BKT model with internal continuous Abelian symmetries is applied.[3]

1- M. Hemmida *et al.*, Phys. Rev. B 80, 054406 (2009).
2- M. Hemmida *et al.*, J. Phys. Soc. Jpn. 80, 053707 (2011).
3- S. A. Bulgadaev, J. Exp. and Theo. Phys. 89, 1107 (1999).

MA 48.60 Thu 15:00 Poster B1

Slow holes in triangular-lattice antiferromagnets: Spin textures and quasiparticle destruction — •Eugen Wolf[1], Eric C. Andrade[2], and Matthias Vojta[1] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Instituto de Física Teórica, Universidade Estadual Paulista, São Paulo, SP, Brazil

We revisit the problem of a single hole doped into a triangular-lattice antiferromagnet with 120° spin order using the t-J model.
Recent work has shown that a static hole induces a non-trivial spin texture due to the release of frustration [1], and we study the fate of this texture upon introducing a finite hopping amplitude.
Our variational results show that the spin texture around a mobile hole is generically given by a superposition of octupolar and dipolar contributions, the latter being responsible for vanishing quasiparticle weight. We determine the single-hole dispersion and connect our results to those from self-consistent Born approximation. Within this approximation, we discuss various hole-spin correlation functions.

[1] Alexander Wollny, Lars Fritz, and Matthias Vojta, Phys. Rev. Lett. 107, 137204

MA 48.61 Thu 15:00 Poster B1

Current-Driven Dynamics of Magnetic Skyrmions in Low Pinning Multilayer Structures at Room Temperature — •Kai Litzius[1,2,3], Ivan Lemesh[4], Lucas Caretta[4], Kornel Richter[1], Benjamin Krüger[1], Markus Weigand[3], Hermann Stoll[3], Gisela Schütz[3], Geoffrey S. D. Beach[4], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Staudinger Weg 9, 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

Magnetic skyrmions are topologically stabilized nanoscale magnetic configurations that are promising for future spintronic devices. Their topology stabilizes them against a continuous deformation into the uniform state and leads to novel physical effects.

Skyrmions have been first predicted in certain magnetic materials due to the Dzyaloshinskii-Moriya interaction (DMI) that favors a chiral spin canting. The interplay between the DMI and the exchange interaction finally gives rise to the creation of skyrmions.

Within the last years, skyrmions have been studied extensively, however no direct observation of real time skyrmion dynamics has been performed so far in for applications relevant geometries. In this work, we report the time-resolved pump-probe observation of stable magnetic skyrmions at room temperature in thin film devices by scanning transmission X-ray microscopy.

MA 48.62 Thu 15:00 Poster B1

Magnon Spectroscopy — •Isabella Boventer[1], Martin Weides[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz, 55128 Mainz — [2]Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe

Within the research in information technology the spin based approach is promising for applications such as data storage, leading to the field of Spintronics. Instead of electrical charge the spin, i.e the magnetic moment of electrons, is utilized. The collective excitation of a spin ensemble results in a spin wave which exhibits a quasiparticle behaviour, termed magnon. We experimentally interface magnons with microwave cavities to investigate dynamics within the magnet. To this end, magnonic elements will be strongly coupled to a resonator, resulting in hybridized magnon - resonator states. Thus, we set up an experiment for the resonant coupling of spin waves in a magnetic bulk or thin film to either a microwave cavity or a coplanar waveguide (CPW) in the strong coupling regime. This will enable both readout at fixed frequency and broadband measurements using network analysis and ferromagnetic resonance (FMR) at various temperatures and magnetic fields. As a first step we characterized the microwave cavity with and without a YIG sphere (⌀ 0.5 mm) in order to reproduce previous results [1,2]. At T = 300 K, we observe a total coupling strength of 50 MHz at B_{dc} = 502 mT. This is almost five times higher than the magnitude reported in [2].

[1] Tabuchi, et al., Phys. Rev. Lett. 113, 083603 (2014)
[2] Zhang, et al., Phys. Rev. Lett 113, 156401 (2014)

MA 48.63 Thu 15:00 Poster B1

Strong coupling of spin-waves and microwave photons in a 3D cavity — •Julius Krause[1], Marco Pfirrmann[1], Oliver Hahn[1], Andre Schneider[1], Sebastian T. Skacel[1], Yannick Schön[1], Isabella Boventer[2], Hannes Rotzinger[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

The model of magnons describes quantized collective excitations of electron spins in a ferromagnet. The spin precession frequency (Larmor frequency) can be adjusted by tuning an external static magnetic field. An alternating magnetic field perpendicular to the static field drives the spin precession. This field component is generated in a cavity in which the electromagnetic field forms a standing wave at resonance conditions. At matching frequencies, cavity photons are able to excite or de-excite magnons.

We experimentally investigate the dynamics of a hybrid quantum system consisting of microwave photons coupled to a ferromagnet. Our goal is to study single magnon excitations at milliKelvin temperatures.

Our experimental setup employs a sub-millimeter YIG sphere within a 3D microwave cavity in an external magnetic field. The cavity provides a sharp resonance of 3 MHz FWHM at 5.3 GHz. In a static magnetic field of 180 mT, the fundamental uniform magnon mode (Kittel mode) matches the cavity resonance frequency. Initial measurements at room temperature show a strong coupling between the Kittel mode and the cavity mode photons with about 30 MHz coupling strength.

MA 48.64 Thu 15:00 Poster B1

Interfacing ferromagnetic magnons with a superconducting qubit — •Marco Pfirrmann[1], Julius Krause[1], Sebastian T. Skacel[1], Andre Schneider[1], Isabella Boventer[2], Hannes Rotzinger[1], Alexey V. Ustinov[1], and Martin Weides[1,2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology — [2]Institut of Physics, Johannes Guttenberg University Mainz

Due to their quantum limited energy resolution and back-action on the measured object, superconducting quantum bits (qubits) are ideal detectors providing information of spectroscopy and coherence. The precessional frequency (Lamor frequency) of collective electron spin excitations (magnons) in a static magnetic field is found in the microwave frequency regime, thereby matching the frequencies of typical level splittings found in superconducting qubits. Such qubits enable the measurement, excitation and manipulation of magnons by choosing a qubit-magnon hybrid with strong coupling. Such a circuit extends the emerging field of classical data processing with magnons (magnonics) into the quantum regime, and aims to achieve quantum information processing with magnons at gigahertz frequencies.

We investigate experimentally a strongly coupled hybrid system consisting of a YIG sphere and a transmon qubit coupled by a 3D microwave cavity at milliKelvin temperatures. We focus on coherent excitation exchange between qubit and magnons to determine the coupling strength and the magnon coherence, i.e. its lifetime and dephasing rates. In this poster we will explain the experimental setup and present initial results.

MA 48.65 Thu 15:00 Poster B1

Dynamics of magnetic skyrmions due to phase-space Berry phases — •Robert Bamler and Achim Rosch — University of Cologne, Germany

We derive a theory for the motion of smooth magnetic whirls (skyrmions) the presence of spin-orbit coupling. Our theory predicts previously disregarded forces due to Berry phases in momentum and in mixed position/momentum space.

In magnetic materials without inversion symmetry (chiral magnets), the magnetization can build up smooth whirls (skyrmions). Lately, the manipulation of skyrmions has been of great interest due to potential applications in future magnetic storage devices. A popular model for skyrmion dynamics is the Thiele equation, which describes a gyrocoupling between external forces and the skyrmion velocity. This can be explained by Berry phases in position space. The Thiele equation neglects, however, Berry phases in momentum space, whose importance is demonstrated by the large anomalous Hall signal in, e.g., MnSi.

In our work, we derive an equation of motion for skyrmions that includes all effects due to phase-space Berry phases. Starting from a microscopic model we derive the classical equation of motion for the skyrmion position using a non-equilibrium field theory approach and a gradient expansion. The resulting equation of motion correctly reproduces the known gyro-coupling and predicts additional forces due to electron drag and due to Berry phases in momentum-space and in mixed position/momentum space. We also discuss the coupling of an external electric field to the electric charge of skyrmions.

MA 48.66 Thu 15:00 Poster B1

Spin-orbit coupling and perpendicular magnetic anisotropy in structural inversion asymmetric stacks — •Samridh Jaiswal[1,2], Berthold Ocker[2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]SINGULUS TECHNOLOGIES AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

The need for low-power data storage in magnetic memory devices for next generation MRAM such as the SOT-MRAM devices requires understanding the magnetisation dynamics in materials envisioned for use in such devices. Ferromagnets (FM) sandwiched between heavy metal (HM) and oxide thin films exhibit novel chiral structures[1,2] arising from an interfacial Dzyaloshinskii-Moriya Interaction. For applications it is most interesting to achieve low threshold currents for switching the magnetic state and to utilise spin orbit torques[3] for manipulation of the magnetisation in systems with a strong perpendicular anisotropy. In this study, the domain structures formed in sputtered thin films of W/CoFeB/MgO and Ta/CoFeB/MgO lacking structural inversion symmetry are studied and their perpendicular magnetic anisotropy is investigated along with the effects of different underlayers. Financial support by the EU Marie Curie ITN project WALL is gratefully acknowledged. [1] A. Fert et al Nat. Nanotechnol. 8(3), 152-156 (2013) [2] N. S. Kiselev et al J. Phys. D. Appl. Phys. 44(39), 392001 (2011) [3] Lo Conte, R. et al Appl. Phys. Lett., 105, 122404 (2014)

MA 48.67 Thu 15:00 Poster B1

Ab initio analysis of the topological phase diagram of the Haldane model — •Julen Ibañez-Azpiroz[1], Asier Eiguren[2], Aitor Bergara[2], Giulio Pettini[3], and Michele Modugno[2] — [1]Peter Grunberg Institute and Institute for Advanced Simulation, Forschungszentrum Julich — [2]University of the Basque Country UPV/EHU — [3]Dipartimento di Fisica e Astronomia, Universita di Firenze

We present an ab initio analysis of a continuous Hamiltonian that maps into the celebrated Haldane model. The tunnelling coefficients of the tight-binding model are computed by means of two independent methods - one based on the maximally localized Wannier functions, the other through analytic expressions in terms of gauge-invariant properties of the spectrum - that provide a remarkable agreement and allow to accurately reproduce the exact spectrum of the continuous Hamiltonian. Our calculations show that the commonly employed Peierls substitution for the complex tunneling coefficient does not provide a reasonable estimate, and we discuss the origin of this feature. Additionally, by combining these results with the numerical calculation of the Chern number, we are able to draw the phase diagram in terms of the physical parameters of the microscopic model. Remarkably, we find that only a small fraction of the original phase diagram of the Haldane model can be accessed, and that the topological insulator phase is suppressed in the deep tight-binding regime.

MA 48.68 Thu 15:00 Poster B1

Investigation of spin-orbit torque effects in topological insulating half-Heusler / ferromagnetic hybrid structures — •Jan Haskenhoff[1,2], Benedikt Ernst[3], Robin Klett[1,2], Karsten Rott[1,2], Claudia Felser[3], and Günter Reiss[1,2] — [1]Physics Department Bielefeld university, 33615 Bielefeld, Germany — [2]Center for Spinelectronic Materials and Devices, Universitätsstraße 25, 33604 Bielefeld, Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Straße 40, 01187 Dresden, Germany

Topological insulators (TI) represent a new quantum state of matter, which host spin-polarized conducting surface channels paired with an insulating bulk. Due to the strong intrinsic spin-orbit coupling, TIs are promising candidates for spin-orbit torque measurements. Furthermore many ternary Heusler compounds are predicted to have topological nontrivial properties. Therefore we investigate spin-orbit torque effects of different TI Heusler / ferromagnetic hybrid structures like e.g. YPdBi/Fe by performing harmonic resistance measurements in a rotating magnetic field up to 1T at a temperature range from 2K to 300K.

MA 48.69 Thu 15:00 Poster B1

Electronic structure of topological insulators — •Michael Czerner, Jonas Friedrich Schäfer, Christian Franz, and Christian Heiliger — Justus Liebig University, Giessen, Germany

We present electronic structure calculations of the topological insulators Bi_2Te_3, Bi_2Se_3, Sb_2Te_3 by means of the Korringa-Kohn-Rostoker Green function method (KKR) based on density functional theory. Since spin-orbit coupling is important for the topological protected surface states, a fully-relativistic treatment is necessary. We show that the electronic structure is very sensitive to the chosen representation of the underlying potentials. We discuss the differences in the results of the atomic sphere approximation in comparison to a full-potential description and show the need of a full-potential calculation to catch the details of the electronic structure.

MA 48.70 Thu 15:00 Poster B1

Spin textures in 3D topological insulator thin films probed with iron-oxide based spin detector — •Lukasz Plucinski[1], Markus Eschbach[1], Ewa Mlynczak[1], Pika Gospodaric[1], Mathias Gehlmann[1], Sven Döring[1], Gustav Bihlmayer[2], Gregor Mussler[3], Detlev Grützmacher[3], Stefan Blügel[2], and Claus M. Schneider[1] — [1]PGI-6, FZ Jülich — [2]PGI-1 and IAS-1, FZ Jülich — [3]PGI-9, FZ Jülich

We will present high resolution spin- and angle-resolved photoemission data of the spin-texture of 3D topological insulator thin films (Bi2Te3, Sb2Te3, Bi2Se3). Spectra were measured using the combination of a hemispherical electron energy analyzer (MBS A1) with an iron-oxide based spin detector (Focus Gmbh Ferrum) which allows measuring one of the in-plane and the out-of-plane spin component of the sample.

We will present new data obtained using He discharge lamp (21.22 eV), Xe microwave source (8.4 eV), and 6 eV laser-based source. We will compare new spectra, taken at an energy resolution down to approx. 30 meV, with our previously published data [1, 2] measured using SPLEED spin detector, where the resolution was 150 meV.

[1] L. Plucinski et al., J. Appl. Phys. 113, 053706 (2013) [2] A. Herdt et al., Phys. Rev. B 87, 035127 (2013).

MA 48.71 Thu 15:00 Poster B1

Stability of Weyl semimetals under the formation of charge density waves — •Christoph Berke, Paolo Michetti, and Carsten Timm — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

In Weyl semimetals, the valence and the conduction bands touch at point, called Weyl points, with a linear dispersion relation. Weyl points are topologically protected and thus stable against small perturbations, but may disappear if they annihilate with other Weyl points. We study an effective $J = \frac{1}{2}$-model for the pyrochlor lattice. Previous studies have predicted the appearance of a Weyl-semimetal phase together with antiferromagnetic all-in-all-out ordering. We are interested in the stability of the Weyl points under the formation of charge density waves that enlarge the unit cell. In the backfolded Brillouin zone, Weyl nodes that were far apart in the antiferromagnetic phase end up close together and could possibly annihilate and get gapped out if this reduces the free energy.

MA 48.72 Thu 15:00 Poster B1

Experimental realization of a topological p-n junction by intrinsic defect-grading — •Thomas Bathon[1], Simona Achilli[2], Paolo Sessi[1], Konstantin Kokh[3], Oleg Tereshchenko[3], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Fisica, Universita Cattolica di Brescia, via dei Musei 41, 25121 Brescia, Italy — [3]Novosibirsk State University, 630090 Novosibirsk, Russia

The extraordinary properties of topological insulators (TIs) are related to linearly dispersing surface states which exhibit chiral spin-momentum-locking. Thereby, backscattering is forbidden and spin currents are intrinsically tied to charge currents. This unconventional spin-texture makes TIs not only fundamentally interesting, but also of great practical importance for applications. Within this framework, the fabrication of topological p-n junctions would represent a pivotal step towards the design of devices with new functionalities.

Here we demonstrate by transport measurements that the different defects inevitably incorporated during the growth process of the prototypical material Bi_2Te_3 result in topological p-n junctions. Atomic-scale STM data combined with *ab-initio* calculations show that this is the result of the different doping character of the various intrinsic defects. The transition region is found to be as narrow as few tens of nm with a built-in potential of approximately 110 meV.

MA 49: Transport: Spintronics and Magnetotransport (Joint session of DS, HL, MA and TT organized by TT)

Time: Thursday 16:15–18:30 Location: H23

Invited Talk MA 49.1 Thu 16:15 H23

Non-Abelian gauge theory description of (dynamical) spin-orbit coupling effects in Fermi gases. — •Cosimo Gorini — Institut für Theoretische Physik, Universität Regensburg, Germany

Spin-orbit coupling heavily influences the dynamics of charge carriers in a solid, where its strength can be enhanced by orders of magnitude as compared to the vacuum. Remarkable consequences are phenomena such as the spin Hall and inverse spin galvanic (or Edelstein) effects, where spin currents and polarizations are generated by purely electrical means. The intricacies of such rich spin-charge coupled dynamics can be described within a non-Abelian gauge theory approach [1], based on Keldysh non-equilibrium formalism [2]. Thanks to a symmetric treatment of spin and charge degrees of freedom, and the removal of ambiguities related to spin non-conservation in the presence of (static or dynamical) spin-orbit coupling, a physically transparent picture is achieved [3]. Furthermore, the non-Abelian language, by virtue of its universal character, treats on the same footing standard spin-orbit interaction in solid state systems and exotic forms of (pseudo) spin-orbit coupling which arise, or can be engineered, in different contexts.

[1] H. Mathur and A. D. Stone, PRL **68**, 2964 (1991)
I. V. Tokatly, PRL **101**, 106601 (2008).
[2] C. Gorini et al., PRB **82**, 195316 (2010).
[3] C. Gorini et al., PRL **109**, 246604 (2012)
C. Gorini et al., PRL **115** , 076602 (2015).

MA 49.2 Thu 16:45 H23

Shot noise in magnetic tunnel junctions: effect of the geometric phase — •Tim Ludwig[1] and Alexander Shnirman[1,2] — [1]Institut für Theorie der Kondensierten Materie, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]L. D. Landau Institute for Theoretical Physics RAS, Kosygina street 2, 119334 Moscow, Russia

We analyze the current driven dynamics of magnetization and voltage in a magnetic tunnel junction. As predicted in [1, 2], the magnetization can be driven by spin currents. This effect can also be reversed, such that an externally driven magnetization generates a dc voltage [3]. Although both effects are intimately related, so far they have been treated separately. We generalize the approach of [4] to derive an action that contains both effects simultaneously. We employ the Keldysh formalism, which allows us to derive stochastic Landau-Lifshitz-Gilbert-Langevin equations describing the angular dynamics of the magnetization coupled with the voltage dynamics. We identify two low-temperature regimes. In one regime the voltage fluctuations are governed by the applied current only, as expected for the shot noise. In the other regime an excess noise arises, which is governed by the geometric phase of the precessing magnetization.

[1] L. Berger, PRB **54**, 9353 (1996)
[2] J. C. Slonczewski, J. Magn. Magn. Mater. **159**, L1 (1996)
[3] L. Berger, PRB **59**, 11465 (1998)
[4] A. Shnirman, Y. Gefen, A. Saha, I. S. Burmistrov, M. N. Kiselev, A. Altland, PRL **114**, 176806 (2015)

MA 49.3 Thu 17:00 H23

Electron transport through the helical molecules in the presence of spin-orbit coupling — •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 it was shown [1] that electron transport through systems with helical symmetry shows spin selectivity. Here we present a theoretical investigation of the transport properties through helical molecules placed between magnetic and nonmagnetic leads by using the DFT and NEGF approach. The performed analysis of the data allow us to show that the systems show spin-polarization only because of spin-orbit interaction and the spin polarization is clearly related to the helical symmetry since a change in handedness of the helix changes the sign of the spin-polarization and a linear chain does not display any sizeable polarization.

[1] B. Göhler, V. Hamelbeck, T. Z. Markus, M.Kettner, G. F. Hanne, Z. Vager, R. Naaman, and H. Zacharias, Science **331**, 894 (2011).

15 min. break

MA 49.4 Thu 17:30 H23

Magnetic impurities on Bi thin films - conductivity and surface diffusion — •Philipp Kröger[1], Sergii Sologub[2], Andreas Lücke[3], Nora Vollmers[3], Uwe Gerstmann[3], Wolf Gero Schmidt[3], Herbert Pfnür[1], and Christoph Tegenkamp[1] — [1]Leibniz Universität Hannover, Inst. für FKP, Appelstr. 2, 30167 Hannover — [2]Inst. of Ph., Nat. Acad. of Sc., Nauky Av. 46, 03028 Kyiv, Ukraine — [3]Universität Paderborn, Theoretische Materialphysik, Pohlweg 55, 33098 Paderborn

The semimetal bismuth has attracted a lot of interest because of its unique electronic properties such as low carrier concentration and large mobility. The surface states reveal a pronounced Rashba splitting. The surface conductivity can well be discriminated from bulk contributions for ultra-thin films grown epitaxially on Si(111) substrates, so that surface related effects are accessible even in macroscopic conductance measurements.

In this context, the adsorption of Cr with its high magnetic moment on the Bi(111) surface will be discussed. Cr induces a transition from Weak Anti- to Weak Localization. This indicates strong impurity scattering that mixes spin and orbit momenta, with corresponding symmetry breaking on the Bi surface (TRS), in agreement with results from DFT calculations. Contrary to other impurities adsorbed at subsurface sites (Fe,Co,Cr, Sb), Cr shows signs of diffusion processes at low T ($T \approx 10$ K), as previously observed for Tb which adsorbes on the surface.

MA 49.5 Thu 17:45 H23

Spin-vibronics in interacting nonmagnetic molecular nanojunctions — •Stephan Weiss[1], Jochen Brüggemann[2], and Michael Thorwart[2] — [1]Theoretische Physik, Universität Duisburg-Essen & CENIDE — [2]1. Institut für Theoretische Physik, Universität Hamburg

We show that in the presence of ferromagnetic electronic reservoirs and spin-dependent tunnel couplings, molecular vibrations in nonmagnetic single molecular transistors induce an effective intramolecular exchange magnetic field[1]. It generates a finite spin-accumulation and -precession for the electrons confined on the molecular bridge and occurs under (non)equilibrium conditions. The effective exchange magnetic field is calculated here to lowest order in the tunnel coupling for a nonequilibrium transport setup. Coulomb interaction between electrons is taken into account as well as a finite electron-phonon coupling. For realistic physical parameters, an effective spin-phonon coupling emerges. It is induced by quantum many-body interactions, which are either electron-phonon or Coulomb-like.

[1] S. Weiss, J. Brüggemann and M. Thorwart,
PRB **92**, 045431 (2015).

MA 49.6 Thu 18:00 H23

Coherent Dynamics of Quantum Spins in Magnetic Environments — •Lars-Hendrik Frahm[1], Christoph Hübner[1], Benjamin Baxevanis[1,2], and Daniela Pfannkuche[1] — [1]1. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany — [2]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA

Leiden, The Netherlands

We investigate equilibration and transport effects of a magnetic atom that is exchange coupled to two electron reservoirs. An effective crystal field, which arises from the substrate the atom is living on gives the spin of the atom an easy axis for alignment. Further, a spin-polarized electron reservoir breaks the rotation symmetry around the spin quantization axis. A proper description of the dynamics of the quantum spin requires to consider the complete density operator, where its knowledge allows to calculate magnetization dynamics and transport properties on an equal footing. We discuss the electron transport through the atomic system by especially focusing on the non-linear influence of the spin torque effect.

MA 49.7 Thu 18:15 H23

Colossal Magnetoresistance observed in Natural Graphite — •Jose Barzola-Quiquia[1], Mahsa Zoraghi[1], Markus Stiller[1], Christian Precker[1], Ana Champi[2], and Pablo Esquinazi[1] — [1]Institute for Experimental Physics II, University of Leipzig, 04103 Leipzig, Germany — [2]Centro de Ciencias Naturais e Humanas Universidade Federal do ABC, Sao Paulo- Brasil

In this work, the electrical transport properties of a bulk natural graphite flake extracted from a mine in Brazil were investigated. The sample showed metallic behavior and the changes in the magnetoresistance (MR) at 5 K and 7 T shows 1123600% change when the field was applied parallel to the *c*-axis. This value was not yet reported in any graphite sample in the literature. Applying constant magnetic field, resistance measurements as a function of the temperature show also a magnetic field induces metal-insulator transition (MIT), with a small critical field $B_0 \approx 10$ mT compared to literature. We observed also that at fields $B > 0.2$ T a metallic reentrance was observed that remains up to ≈ 50 K. STEM measurements reveal the presence of interfaces in the investigated material. Therefore, the observed transport properties are not an intrinsic behavior of the graphite sample but due to the presence of these interfaces. Interfaces in the sample are formed at the interfaces between two crystalline regions inside the sample where a two dimensional electron gas (2DEG) system appears. Raman measurements reveal that our samples are free from any other defects.

MA 50: General Meeting of the Magnetism Division (Fachverband Magnetismus)

For further information visit the website of the Magnetism Division (Fachverband Magnetismus) at http://www.dpg-physik.de/dpg/gliederung/fv/ma .

Time: Thursday 18:30–19:30 Location: H32

All members of the Magnetism Section are requested to attend.

MA 51: Magnetic Semiconductors

Time: Friday 9:30–11:30 Location: H13

MA 51.1 Fri 9:30 H13

A systematic investigation of the magnetic anisotropy of III-Mn-V ferromagnetic semiconductors — •Chi Xu[1,3], Ye Yuan[1,3], Maciek Sawicki[2], Manfred Helm[1,3], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany — [2]Institute of Physics, Polish Academy of Sciences, Warszawa, Poland — [3]Technische Universität Dresden, D-01062 Dresden, Germany

As one of the most important physical properties of dilute ferromagnetic semiconductors (DFS), the magnetic anisotropy exhibits a complicated character and its origin is under continuous discussion [1]. Due to different physical parameters (e.g. band gap, lattice constant) in various Mn doped III-V DMSs, various magnetic anisotropies are expected and could be tailored by Mn or hole concentrations [2,3]. To investigate this in greater detail, we prepare three typical III-Mn-V DFSs, InMnAs, GaMnAs, and GaMnP by ion implantation and pulsed laser annealing, which is a complementary approach to low-temperature molecular beam epitaxy. We report a systematic investigation on the magnetic anisotropy with the aim to understand its physical origin.

[1]. T. Dietl et al., Rev. Mod. Phys. 86, 187-251 (2014) [2]. M. Sawicki et al., Phys. Rev. B 70, 245325 (2004) [3]. C. Bihler et al., Phys. Rev. B 78, 045203 (2008)

MA 51.2 Fri 9:45 H13

Application of ion beams to fabricate and tune ferromagnetic semiconductors — •Shengqiang Zhou — Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany

In this talk, I will show how ion beams can be used in fabricating and understanding ferromagnetic semiconductors. First, ion implantation followed by pulsed laser melting (II-PLM) provides an alternative to the widely used low-temperature molecular beam epitaxy (LTMBE) approach [1-7]. Going beyond LT-MBE, II-PLM is successful to bring two new members, GaMnP and InMnP, into the family of III-V:Mn. Both GaMnP and InMnP films show the signature of ferromagnetic semiconductors and an insulating behavior. Second, we use helium ion irradiation to precisely compensate holes in ferromagnetic semiconductors while keeping the Mn concentration constant [8-10]. By this approach, one can tune the magnetic properties of ferromagnetic semiconductor as well as pattern a lateral structure. It also provides a route to understand how carrier-mediated ferromagnetism is influenced by localization.

[1] M. Scarpula, et al. PRL 95, 207204 (2005); [2] D. Bürger, S. Zhou, et al., PRB 81, 115202 (2010); [3] S. Zhou, et al., Appl. Phys. Express 5, 093007 (2012); [4] M. Khalid et al., PRB 89, 121301(R) (2014); [5] Y. Yuan, et al, IEEE Trans. Magn. 50, 2401304 (2014); [6] Y. Yuan, et al. JPD 48, 235002 (2015); [7] S. Zhou, JPD 48, 263001 (2015); [8] Lin Li, et al., JPD 44 099501 (2011); [9] Lin Li, et al., NIMB, 269, 2469 (2011); [10] S. Zhou, et al. PRB, in revision (2015).

MA 51.3 Fri 10:00 H13

Effective Spin Models and Critical Temperatures for Diluted Magnetic Semiconductors. — Richard Bouzerar[1], •Daniel May[2], Ute Löw[2], Denis Machon[1], Patrice Melinon[1], and Georges Bouzerar[1] — [1]Institut Lumière Matière, CNRS et Université Lyon 1, 69622 Villeurbanne Cedex, France — [2]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44221 Dortmund, Germany

Diluted magnetic semiconductors (DMS) are materials where magnetic ions substitute a small percentage of the host's cations. We use a one-band VJ model with three adjustable parameters to describe DMS and extract long-range spin-spin couplings. These couplings are subsequently used as input to a classical Heisenberg model which is studied by Monte Carlo simulation (MC) and a self-consistent approach based on Green's functions (L-RPA). Both methods treat random lattice configurations beyond the standard Mean Field Approximation and without resorting to an effective medium. Our focus lies mainly on (In,Mn)P for small concentrations $x < 0.1$ of manganese where critical temperatures of 20-40 K are expected. The L-RPA provides us with a self-consistent expression for T_c whereas we use finite size scaling for the MC results to calculate a reliable critical temperature. Our goal is to provide a consistent description of recent experimental results for the magnetic properties of the Mn-doped InP diluted magnetic semiconductor.

30 min. Coffee Break

MA 51.4 Fri 10:45 H13

Long-range p-d exchange interaction in a ferromagnet-semiconductor hybrid structure — •Matthias Salewski[1], Vladimir L. Korenev[1,2], Ilya A. Akimov[1,2], Victor V. Sapega[2,3], Lukas Langer[1], Ina V. Kalitukha[2], Jörg Debus[1], Roslan I. Dzhioev[2], Dmitri R. Yakovlev[1,2], David Müller[1], Chrstoph Schröder[4], Heinz Hövel[4], Grzegorz Karczewski[5], Maciej Wiater[5], Tomasz Wojtowicz[5], Yuri G. Kusrayev[2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Physical Faculty of St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Experimentelle Physik 1, Technische Universität Dortmund, D-44221 Dortmund, Germany — [5]Institute of Physics, Polish Academy of Sciences, PL-02668 Warsaw, Poland

The magnetic coupling in hybrid structures composed of semiconductor (SC) nanostructures and ferromagnetic layers (FM) typically depends on the wave function overlap of SC charge carriers (p-system) and FM ions (d-system) and is therefore short-ranged. Here we report on a hybrid system with surprisingly long-ranged, robust coupling that does not vary with spacer width up to more than 30 nm. We suggest that the resulting spin polarization of acceptor-bound holes is induced by an effective p-d exchange that is mediated by elliptically polarized phonons.

MA 51.5 Fri 11:00 H13

Site resolved band structure of a diluted magnetic semiconductor — •Slavomir Nemsak[1], Mathias Gehlmann[1], Cheng-Tai Kuo[2], Tien-Lin Lee[3], Lukasz Plucinski[1], Claus M. Schneider[1], and Charles S. Fadley[2] — [1]Forschungszentrum Juelich, Germany — [2]UC Davis, CA, USA — [3]Diamond Light Source, Didcot, GB

Standing wave (SW) photoemission of core-levels and valence electrons at the density-of-states limit has proven to be a very potent and powerful method, especially for investigating electronic properties of the buried interfaces, either solid/solid [Gray et al., EPL 104, 17004 (2013)], but also solid/liquid and liquid/gas [Nemsak et al., Nat. Comm. 5, 5441 (2014)]. The exceptional depth selectivity provides a key to the depth-resolved information, which is very difficult to extract by other, less direct, methods.

The combination of the SW approach and hard X-ray angle resolved photoelectron spectroscopy (HARPES) [Gray et al., Nature Mat. 11, 957 (2012)] takes these efforts one step further. The strengths of the SW-HARPES method are demonstrated on the example of diluted magnetic semiconductor Ga(Mn)As. A strong SW is generated using hard X-ray excitation of ca. 3 keV using the (111) reflection of the undoped GaAs substrate and the 5% Mn-doped thin film with. Due to the uneven occupancy of (111) planes by either Ga(Mn) or As atoms, the element specific band structure can be obtained with a help of the SW modulation in core levels. Apart from the site specific decomposition of the electronic structure, the SW measurement confirmed a substitutional presence of Mn atoms at the Ga sites.

MA 51.6 Fri 11:15 H13

Modeling Magnetism of Diluted Magnetic Systems using the Gutzwiller Method — •Thorben Linneweber[1], Ute Löw[1], Florian Gebhard[2], and Jörg Bünemann[2] — [1]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44221 Dortmund — [2]Philipps-Universität Marburg, AG Vielteilchenphysik, 35032 Marburg

Diluted magnetic semiconductors are materials in which magnetic ions substitutionally or interstitially replace a fraction of the cations of the semiconductor host material. We aim to describe the magnetic properties of the prototype substance $Cd_{1-x}Mn_xTe$. We derive a multiband Hubbard model from DFT calculations using the Wannier90 code. Large unit cells (≈ 200 atoms) account for the randomized substitution of cations by magnetic ions. We analyze the ground state of this model within the framework of the Gutzwiller variational method. We find that the d-shell of the Mn ions resembles an atomic Hund's rule S=5/2 ground state. Due to the superexchange mechanism, there is an effective short-range Heisenberg exchange between the magnetic ions. We estimate the exchange parameters using energy calculations of different magnetic configurations and finally compare them to experimental results.

MA 52: Focus: Ultrafast spin currents for spin-orbitronics: from metals to topological insulators

Organized by Y. Mokrousov (FZ-Jülich) and M. Münzenberg (U. Greifswald)

Engineering relativistic spin-charge entanglement in complex multi-functional materials allows for novel ways of spin control. At the heart of newly discovered phenomena in the field of spinorbitronics is the relativistic spin-orbit interaction, which leads to a multitude of phenomena related to relativistic scattering, spin Hall effect and spin current generation, currently all of central interest in a spectrum of materials ranging from common metals to exotic topological insulators. The effect of spin-orbit torque (SOT) relies on the spin-orbit interaction in combination with ferromagnetic magnetization and broken inversion symmetry, and it can be used to successfully switch the magnetization of ferromagnets with electric field. While the SOT is a candidate for non-volatile random access and cache memories, the design of future relativistic spintronics devices relies on a deep microscopic understanding of coupled phenomenona taking place in prototypical experimental setups. Furthermore, to achieve ultrafast switching dynamics in these devices, the exploration and understanding of non-equilibrium spin-orbit physics at high frequencies is of utter importance. Spin-orbit effects at femtosecond time scale are believed to be very important for spin momentum redistribution in the presence of laser field-driven currents, and this issue is heavily debated at the moment. In this focus session we highlight the very recent developments related to the interplay of spin-orbit interaction and ultrafast currents in diverse materials.

Time: Friday 9:30–12:15 Location: H32

Invited Talk MA 52.1 Fri 9:30 H32

Experimental separation of various mechanisms leading to laser-pulse-induced magnetization precession in (Ga,Mn)As — •Petr Nemec — Charles University in Prague, Ke Karlovu 3, 121 16 Prague 2, Czech Republic

Ferromagnetic semiconductor (Ga,Mn)As is a favorable material for observing optical spin torques because the direct-gap GaAs host allows the generation of high density non-equilibrium photo-carriers and the carrier spins interact with ferromagnetic moments on Mn via strong exchange coupling [1]. In this contribution we show how various excitation mechanisms leading to laser-pulse-induced magnetization precession in (Ga,Mn)As can be experimentally separated. In particular, we demonstrate how the optical spin transfer torque, which is a non-relativistic phenomenon where angular momentum of spin polarized electrons photoinjected by circularly polarized laser pulse is transferred to the magnetization [2], and optical spin-orbit torque, which is a relativistic phenomenon originating from spin-orbit coupling of non-equilibrium photocarriers [3], can be separated from each other and from the thermal mechanism. We also illustrate how the laser-induced magnetization dynamics can be used for a determination of magnetic parameters of (Ga,Mn)As [4] and other materials.

[1] T. Jungwirth et al., Rev. Mod. Phys. 86, 855 (2014). [2] P. Ne-

mec et al., Nature Physics 8, 411 (2012). [3] N. Tesarova et al., Nature Photonics 7, 492 (2013). [4] P. Nemec et al., Nature Communications 4:1422 (2013).

Invited Talk MA 52.2 Fri 10:00 H32
Ultrafast photocurrents and quantized conductance in 3D topological insulators — •Alexander Holleitner — Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, 85748 Garching

We demonstrate that helicity-dependent photocurrents in 3D topological insulators can be controlled and read-out on a time-scale of a picosecond with near-unity fidelity even at room temperature [1,2]. Our experiments reveal the temporal interplay of such ultrafast spin currents with photo-induced thermoelectric currents of hot electrons in the optoelectronic circuits. Moreover, we verify millimeter-scale edge channels in bismuth chalcogenides with a quantized conductance of 1 e^2/h at zero magnetic field. In optoelectronic experiments [3], the quantum transport is found at the lateral edges of the 3D topological insulators and is explained by a one-dimensional quantum confinement of non-topological surface states with a strong Rashba spin-orbit coupling [4].

We thank C. Kastl, P. Seifert, C. Karnetzky, H. Karl, X. He, K. Wu, and Y. Li, for a very fruitful collaboration, and the DFG-SPP-1666 'Topological insulators' and the ERC-grant 'NanoREAL' for financial support.

[1] L. Prechtel et al. Nature Comm. 3, 646 (2012).
[2] C. Kastl et al. Nature Comm. 6, 6617 (2015).
[3] C. Kastl et al. 2D Materials 2, 024012 (2015).
[4] C. Kastl et al. (2016).

15 min. break

Invited Talk MA 52.3 Fri 10:45 H32
Real-time time-dependent DFT for spin dynamics in magnets — •Stefano Sanvito, Maria Stamenova, and Jacopo Simoni — School of Physics and CRANN, Trinity College, Dublin 2, Ireland

Ultra-fast laser-driven spin dynamics is rapidly becoming a tool to manipulate the magnetic interaction at the femtosecond timescale. In this limit both the magnetic exchange and the anisotropy become time-dependent and the modelling of the spin-dynamics must be carried out at the electronic level. Here we show how real time time-dependent density functional theory can be used to understand the first femtoseconds of the laser-induced spin dynamics of magnetic transition metals. In particular we will present the case of both finite magnetic clusters and bulk transition metals. We will show how the demagnetisation immediately following the laser excitation is uniquely driven by the strength of the spin-orbit interaction, and how it relates to oscillations of the charge density between the core and the interstitial regions. Furthermore, we will demonstrate how such rapid demagnetisation is affected by the laser intensity and polarisation, and how it scales with the size of the system under investigation.

Invited Talk MA 52.4 Fri 11:15 H32
Spin transport and spin-orbit interaction at terahertz frequencies: spectroscopy and applications — •Tom Seifert — Fritz-Haber-Institute, Berlin, Germany

On the route toward spin-based electronics (spintronics), spin-orbit interaction (SOI) is envisioned to play a major role since it permits spin-to-charge conversion and vice versa via the spin Hall effect (SHE). To study the dynamics of the SHE and related effects, terahertz (THz) time-domain spectroscopy is a promising tool because THz photon energies (4 meV at 1 THz) are comparable with the energy scale of SOI (1-100 meV). At the same time, future spintronic devices should eventually operate at such elevated frequencies.
Here, we use two complementary approaches to address the interplay of SOI, electron and spin transport at THz frequencies. First, we employ broadband THz time-domain ellipsometry [*A. Rubano et al., APL (2012)*] to measure the anomalous Hall effect in various magnetic metals from 1 to 40 THz. Second, we use femtosecond laser pulses (800 nm, 10 fs, 2 nJ) to induce ultrafast spin currents in magnetic heterostructures which, through the inverse SHE, lead to emission of THz radiation [*T. Kampfrath et al., NatNano (2013)*]. Detection of the latter allows us to measure the spin current and the spin Hall angle in a contactless manner. Finally, optimization of these structures results in new, efficient, scalable and ultrabroadband emitters of THz electromagnetic pulses [*T. Seifert et al., http://arxiv.org/abs/1510.03729 (2015)*].

Invited Talk MA 52.5 Fri 11:45 H32
Driving currents by magnetization dynamics in systems with broken inversion symmetry — •Frank Freimuth — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

By breaking the inversion symmetry in crystals, one switches on the correlation between axial and polar vectors, which otherwise would be forbidden by symmetry. In magnetic crystals one can thereby generate torques on the magnetization by applying electrical or heat currents, the so-called spin-orbit torques. Conversely, magnetization dynamics induces currents, which is the inverse spin-orbit torque effect. At small frequencies, i.e., under typical FMR conditions, the inverse spin-orbit torque can be understood in terms of spin pumping combined with the spin-Hall effect and the Rashba or Dresselhaus spin-orbit fields. However, when magnetic solids are excited by femtosecond laser pulses, additional effects set in, such as the generation of ultradiffusive spin-currents and ultrafast demagnetization, which lead to new mechanisms for generating electrical currents in inversion asymmetric magnets. Using the Kubo linear response formalism we systematically identify mechanisms behind the generation of electrical currents in the range from FMR up to optical frequencies, discovering also several new effects. In particular, we find that not only precession of magnetization, but also demagnetization, drive currents. Based on DFT calculations we investigate these effects in Co/Pt and Mn/W bilayers as well as in the half-Heusler compound PtMnSb and elucidate the role that spin-currents play.

MA 53: Magnetic Scattering Methods

Time: Friday 9:30–11:45 Location: H33

MA 53.1 Fri 9:30 H33
Growth and interfacial properties of FePt/Fe/NiO and FePt/NiO/Fe trilayers — •Amir Syed Mohd, Sabine Pütter, Stefan Mattauch, Alexandros Koutsioubas, and Thomas Brückel — Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, Garching, Germany

The exchange coupling between different types of magnetic thin films has opened possibilities to develop functional nanostructures. This phenomenon is governed mainly by the interfacial properties and emerges as exchange bias effect [when a ferromagnet (e.g. Fe) is coupled with an antiferromagnet (e.g. NiO)] and as exchange spring effect [when a hard ferromagnet (e.g. FePt) is coupled with a soft ferromagnet (e.g. Fe)] in bilayers and multilayers [1, 2].

In this work we have deposited FePt/Fe/NiO and FePt/NiO/Fe trilayers using molecular beam epitaxy (MBE) method on MgO(001) under similar conditions. In-situ reflection high energy electron diffraction (RHEED) patterns show that the growth morphologies of Fe/NiO and NiO/Fe are different and lead to epitaxial and textured growth respectively. In order to study the interfacial properties, ex-situ x-ray reflectivity (XRR) and polarised neutron reflectivity (PNR) have been performed. XRR and PNR results indicate that deposition of NiO on Fe forms a complex structure of Fe-O at the interface as a result magnetic coupling is suppressed between Fe and NiO. The obtained results will be discussed in more detail during presentation.

[1] P. K. Manna et al., Physics Reports 535, 61 (2014). [2] N. de Sousa et al., Phys. Rev. B 82, 104433 (2010).

MA 53.2 Fri 9:45 H33
Quenching of the Resonant Magnetic Scattering by Ultra-Short Free-Electron Laser Light Pulses — •Leonard Müller[1], Magnus H. Berntsen[2], Wojciech Roseker[1], Kai Bagschik[3], Jochen Wagner[3], Robert Frömter[3], Flavio Capotondi[4], Emanuele Pedersoli[4], Michele Manfredda[4], Miltcho B.

Danailov[4], Maya Kiskinova[4], Hans P. Oepen[3], and Gerhard Grübel[1] — [1]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany — [2]KTH, Stockholm, Sweden — [3]University 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 in highly excited states which are otherwise inaccessible.

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

MA 53.3 Fri 10:00 H33

Study of the Spin-Chain cuprate Sr2CuO3 with OK-edge Resonant Inelastic X-ray Scattering — •Justine Schlappa[1,2], Umesh Kumar[3], Ke-Jin Zhou[2,4], Surjeet Singh[5,6], Vladimir N. Strocov[2], Alexandre Revcolevschi[4], Henrik M. Ronnow[7], Steve Johnston[3], and Thorsten Schmitt[2] — [1]European X-ray Free Electron Laser Facility GmbH, Hamburg, Germany — [2]Paul Scherrer Institut, Villigen, Switzerland — [3]University of Tennessee, Knoxville, USA — [4]Diamond Light Source, Oxfordshire, UK — [5]Université Paris-Sud, Orsay, France — [6]Indian Institute of Science, Education and Research, Pune, India — [7]École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

We present the study of Heisenberg Spin-1/2 chain compound Sr2CuO3 with oxygen K-edge Resonant Inelastic X-ray Scattering. The spectra reveal a range of low-energy excitations between tens of meV and 8 eV. From small-cluster exact diagonalization calculations the structures at higher energies can be assigned to dd and charge-transfer excitations, whereas the structures below 1 eV partially to spin- and phonon excitations. The photon wave length allowed accessing half of the Briolluin zone in this study.

MA 53.4 Fri 10:15 H33

Avoided ferromagnetic criticality in PrPtAl — •Dmitry Sokolov[1,2], Andrew Huxley[1], and Frank Krueger[3,4] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]School of Physics & Astronomy, The University of Edinburgh, UK — [3]ISIS, STFC, Rutherford Appleton Laboratory, Chilton, UK — [4]London Centre for Nanotechnology, University College London, London, UK

Our recent work on induced moment ferromagnet PrPtAl provided a first experimental evidence for intermediate electronic states, which precede the conventional q=0 ferromagnetism when the ferromagnetic transition temperature is close to zero. Using the neutron diffraction and synchrotron X-ray scattering we have shown that with decreasing temperature PrPtAl undergoes a transition from paramagnetic state into a doubly modulated incommensurate spin density wave (SDW), followed by a second transition at lower temperature in to a single incommensurate SDW of a different period before transitioning into a commensurate ferromagnetism at the lowest temperatures [1]. This finding represents the first new paradigm for understanding the transition from paramagnetism to ferromagnetism since the formulation of the theory of the continuous phase transitions by L. D. Landau in 1937.

[1] G. Jabbar, D. A. Sokolov, C. O' Neill, C. Stock, D. Wermeille, F. Demmel, F. Krueger, A. G. Green, F. Levy-Bertrand, B. Grenier, and A. D. Huxley, Nat. Phys. 11, 321 (2015).

15 min. break

MA 53.5 Fri 10:45 H33

Anomalous thermal decoherence in a quantum magnet measured with neutron spin-echo spectroscopy — •Felix Groitl[1,2,3], Klaus Habicht[3], Katharina Rolfs[2], Thomas Keller[4,5], and Alan Tennant[3,6] — [1]Ecole Polytechnique Federale de Lausanne, 1015 Lausanne, Switzerland — [2]Paul Scherrer Institut, 5232 Villigen, Switzerland — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 14109 Berlin, Germany — [4]Max Planck Institute For Solid State Research, 70569 Stuttgart, Germany — [5]Max Planck Society Outstation at the FRM II, 85748 Garching, Germany — [6]Technische Universität Berlin, Institut für Festkörperphysik, 10623 Berlin, Germany

The effect of temperature dependent asymmetric line roadening is investigated in $Cu(NO_3)_2 \cdot 2.5D_2O$, a model material for a 1-D bond alternating Heisenberg chain, using the high resolution neutron-resonance spin-echo (NRSE) technique. Inelastic neutron scattering experiments on dispersive excitations including phase sensitive measurements demonstrate the potential of NRSE to resolve line shapes, which are non-Lorentzian, opening up a new and hitherto unexplored class of experiments for the NRSE method beyond standard line width measurements. The particular advantage of NRSE is its direct access to the line shape in the time domain without convolution with the resolution function of the background spectrometer. This novel application of NRSE is promising and establishes a basis for further experiments on different systems, since the results for $Cu(NO_3)_2 \cdot 2.5D_2O$ are applicable to a broad range of quantum systems.

MA 53.6 Fri 11:00 H33

CAMEA - A novel multiplexing analyzer for neutron spectroscopy — •Felix Groitl[1,2], Dieter Graf[2], Jonas Birk[2], Marton Marko[2,3], Marek Bartkowiak[2], Uwe Filges[2], Christof Niedermayer[2], Christian Rüegg[2,4], and Henrik Ronnow[1,5] — [1]Ecole Polytechnique Federale de Lausanne, 1015 Lausanne, Switzerland — [2]Paul Scherrer Institut, 5232 Villigen, Switzerland — [3]Wigner Research Centre for Physics, 1525 Budapest, Hungary — [4]University of Geneva, 1211 Geneva, Switzerland — [5]University of Copenhagen, 2100 Copenhagen, Denmark

The analyzer system CAMEA (Continuous Angle Multiple Energy Analysis) will be installed as a new secondary spectrometer on the cold-neutron triple-axis spectrometer RITA-2 at SINQ, PSI. CAMEA is optimized for efficiency in the horizontal scattering plane enabling detailed and rapid mapping of excitations. As a novelty the design employs a series of several sequential upward scattering analyzer arcs. Each arc is set to a different, fixed final energy scattering towards position sensitive detectors. Thus, neutrons with different final energies are collected simultaneously over a large angular range. For CAMEA in a single data-acquisition several entire constant-energy lines in the horizontal scattering plane are recorded for a quasi-continuous angular coverage of about 60°. With a large combined coverage in energy and momentum, this will result in a very powerful and efficient spectrometer, which will be particularly suited for parametric studies under extreme conditions with restrictive sample environments (high field magnets or pressure cells) and for small samples of novel materials.

MA 53.7 Fri 11:15 H33

Element specific magnetization redistribution at YBa2Cu3O7-La0.66Ca0.33MnO3 interfaces — •Aurora Alberca[1,2], Miguel Angel Uribe Laverde[2], Yoah William Windsor[1], Mahesh Ramakrishnan[1], Laurenz Rettig[1], Ivan Marozau[2], Jean-Marc Tonnerre[3,4], Jochen Stahn[5], Urs Staub[1], and Christian Bernhard[2] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [2]University of Fribourg, Department of Physics and Fribourg Centre for Nanomaterials, Chemin du Musee 3, CH-1700 Fribourg, Switzerland — [3]Université Grenoble Alpes, Institut NEEL, F-38042 Grenoble, France — [4]CNRS, Institut NEEL, F-38042 Grenoble, France — [5]Laboratory for Neutron Scattering, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland

We study the element specific magnetic depth profiles of a YBa2Cu3O7 La0.66Ca0.33MnO3 (YBCO LCMO) superlattice using soft X-ray Resonant Magnetic Reflectometry (XRMR). The element specific depth profiling capability of XRMR allows us to study the magnetic proximity effect (MPE) that is observed at the YBCO LCMO interface. MPE is characterized by the occurrence of a depleted layer on the manganite side and an induced magnetization in the YBCO. We show that the Cu moments (0.28 muB per interfacial Cu ion) reside on the YBCO side of the interface and originate from the CuO2 plane that is located at the interface.

[1] Alberca et al., Physical Review B 92 (17), 174415

MA 53.8 Fri 11:30 H33

Imaging of magnetic nanodots utilizing soft x-ray holographic microscopy — •Jochen Wagner[1], Kai Bagschik[1], Stefan Freercks[1], Carsten Thönnissen[1], André Kobs[1,2], Robert Frömter[1], Leonard Müller[2], Magnus H. Berntsen[3], 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 Fourier transform holography (FTH) has become a competitive technique to investigate magnetic samples with up to sub-20 nm spatial resolution exploiting the x-ray magnetic circular dichroism [1].

We used this technique to image arrays of nanodots with perpendicular magnetization. The nanodots are structured by e-beam lithography from a (Co (0.8 nm)/Pt (0.8 nm))$_8$ multilayer film prepared by dc magnetron sputtering and ion assisted sputtering on 200 nm thick Si_3N_4 membranes. The diameter of the dots is 60 nm and the interdot spacing of the arrays varies from 100 to 160 nm.

We prepare the arrays in a state of randomized magnetization. The system is step-by-step magnetized. Averaged information about the magnetic state of the dots at different magnetic fields can be extracted from the intensity of the Bragg peaks even in single helicity holograms. By simulation the key features of the holograms can be reproduced and correlated to the magnetic state imaged by FTH.

[1] D. Stickler, et al., Appl. Phys. Lett. 96, 042501 (2010).

MA 54: Electron Theory of Magnetism and Micromagnetic Simulations

Time: Friday 9:30–13:00 Location: H34

Invited Talk MA 54.1 Fri 9:30 H34

Itinerant Magnetism in the Parent Iron-Based Superconductors: hidden frustration, nematic transitions, and spin-orbit coupling — •Ilya Eremin — Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany

The pnictides have captured the imagination of the condensed matter community mainly on account of their high Tc's exceeding 50K. However, underpinning this is an equally fascinating topic, namely their magnetic properties, which have been studied in exquisite detail for a range of compounds unusually broad for an itinerant magnet.

This talk will cover rich phase diagram as function of doping, pressure, displaying e.g. separate magnetic and nematic critical points. It showcases important topics such as the interplay of orbital, nematic and magnetic order on account of the orbital character of the Fermi pockets involved. Experimental signatures of these phenomena will be also discussed.

15 min. break

MA 54.2 Fri 10:15 H34

The Gilbert damping in random ferromagnetic alloys from the LMTO method — •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 an *ab initio* theory of the Gilbert damping tensor for spin-polarized random alloys within the relativistic tight-binding LMTO method and the coherent potential approximation (CPA) [1]. The formulation employs the atomic-sphere approximation which leads to effective nonlocal torque operators entering the LMTO torque-correlation formula. In contrast to traditional local torque operators [2, 3], the nonlocal torques are nonrandom and spin-independent; the CPA-vertex corrections are indispensable for an exact equivalence of both torques. The developed theory has been applied to random ferromagnetic alloys of 3*d* elements (Fe, Co, Ni), to pure iron with a model atomic-level disorder (simulating the effect of a finite temperature), and to stoichiometric FePt alloys with a varying degree of the $L1_0$ atomic long-range order. [1] I. Turek et al., arXiv: 1510.03571 (2015). [2] H. Ebert et el., Phys. Rev. Lett. 107, 066603 (2011). [3] A. Sakuma, J. Phys. Soc. Japan 81, 084701 (2012).

MA 54.3 Fri 10:30 H34

Influence of spin-orbit coupling on the magnetic dipole term T_z in XMCD sum rules — •Ondrej Sipr[1], Hubert Ebert[2], and Jan Minar[2,3] — [1]Institute of Physics ASCR, Prague — [2]Ludwig-Maximilians-Universität, München — [3]University of West Bohemia, Pilsen

Sum rules are a powerful tool for interpreting x-ray magnetic circular dichroism (XMCD) spectra: they give access to m_{spin} and m_{orb} separately. However, these rules provide m_{spin} only in a combination as $m_{\mathrm{spin}} + 7T_z$, where T_z is the expectation value of the intra-atomic dipole operator ("magnetic dipole term"). While T_z can be usually neglected in the bulk, it can be large for surfaces, monolayers and clusters where, additionally, a considerable anisotropy of T_z is expected.

Interpretation of T_z often relies on an approximate expression for T_z valid if spin-orbit coupling (SOC) can be neglected. In that case, moreover, T_z depends on the direction of magnetization in a specific way, allowing for its elimination from XMCD experiment by doing measurements at the magic angle. Therefore, it is desirable to check whether the effect of SOC on T_z can or cannot be neglected.

We calculated T_z for Co monolayers and adatoms on noble metals (Cu, Ag, Au, Pd, Pt). We found that the effect of SOC on T_z can be neglected for monolayers but not for adatoms. Simple intuition or the magic-angle-based elimination of T_z from XMCD data thus cannot be used for adatoms or clusters which, at the same time, are systems where T_z is very important.

MA 54.4 Fri 10:45 H34

Implementation of the Relativistic DLM scheme within the SPR-KKR method: Finite temperature magnetic properties of metals and alloys. — •Sergiy Mankovsky and Hubert Ebert — Dept. Chemie, Universität München, D-81377 München, Deutschland

The relativistic disordered local moment (RDLM) method [1,2] has been implemented within the fully relativistic spin polarized KKR band structure method. Corresponding electronic structure calculations within this approach, that account self-consistently for temperature induced magnetic disorder, allows to go beyond the rigid spin approximation. This important step may be crucial in particular for itinerant electron magnetic materials and gives access to a more reliable investigation of various temperature dependent magnetic properties (e.g. average magnetization, magnetic anisotropy or transport properties). To illustrate the capability of this approach, calculations have been performed both for pure materials as well as for compounds. The results are compared with those obtained by other methods and with the experimental data.

[1] J. B. Staunton et al., Phys. Rev. B **74**, 144411 (2006)
[2] A. Deak et al., Phys. Rev. B **89**, 224401 (2014)

MA 54.5 Fri 11:00 H34

A detailed view on the effect of the spin-orbit coupling on the magnetocrystalline anisotropy: case study of FePt — •Saleem Ayaz Khan[1], Peter Blaha[2], Hubert Ebert[3], Jan Minar[1,3], and Ondrej Sipr[1,4] — [1]University of West Bohemia, Pilsen — [2]Technische Universität Wien — [3]Ludwig-Maximilians-Universität München — [4]Institute of Physics ASCR, Prague

To obtain magnetocrystalline anisotropy (MCA) energy via ab-initio calculations, the spin orbit coupling (SOC) has to be accounted for. This can be done either fully by solving the relativistic Dirac equation or pertubatively via the second variation approach. To assess whether employing one or the other method has got a significant impact on the calculated magnetocrystalline anisotropy is not trivial: different ways of dealing with the SOC are implemented in different codes which rely on different methods and as the MCA energy is very sensitive to various technical parameters, a very careful examination of various convergence parameters has to be performed to get a meaningful comparison. Our study of the MCA of bulk FePt focuses on comparison of results of the Wien2k FLAPW code, where the SOC is implemented via the second variation approach, and of the SPRKKR code, where the Dirac equation is solved using a full-potential KKR Green function method.

15 min. break

MA 54.6 Fri 11:30 H34

Chiral bobbers new type of stable particle like states in chiral magnets — Filipp N. Rybakov[1], Alexander B. Borisov[1], Stefan Blügel[2], and •Nikolai S. Kiselev[2] — [1]M. N. Miheev Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Ekaterinburg 620990, Russia — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We present a recently discovered new type of a thermodynamically stable magnetic quasi-particle, which appears at interfaces, and surfaces of isotropic chiral magnets [1]. Because of the essential chirality of such a state and its localization close to the surface with the finite penetration depth, like a fishing bobber at a water surface, we use term chiral bobber (ChB) to refer to this object. The ChB is a soliton solution of micromagnetic equations localized in all three dimensions. It constitutes a new class of particles the hybrid particles composed of a smooth magnetization field and a magnetic singularity (Bloch point). Both contribute to three-dimensional torque fields and interesting dynamical and electron transport properties. Such new particle like state exhibits high thermal stability and thereby can be considered as promising object for fundamental research and practical applications in spintronic devices. We provide arguments that such a state can be found in different Si or Ge based B20-type alloys.

[1] F.N. Rybakov, A.B. Borisov, S. Blügel, & N.S.Kiselev, New type of stable particle like states in chiral magnets. Phys. Rev. Lett. 115, 117201 (2015).

MA 54.7 Fri 11:45 H34

Skyrmionic magnetization switching in nanorods — •Michalis Charilaou[1], Hans-Benjamin Braun[2], and Jörg Friedrich Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, Switzerland — [2]School of Physics, University College Dublin, Ireland

Magnetization switching mechanisms in nanorods, i.e., cylindrical nanowires, have been investigated in great detail, experimentally, theoretically, and computationally, because of their promising potential for technological implementation in data-storage devices. Depending on the shape, dimension, and anisotropic properties of a nanowire, possible reversal mechanisms are quasi-coherent rotation, domain-wall nucleation, and curling, all of which can transform the magnetization continuously from one state to another. In this work, we will show via micromagnetic simulations that in nanorods the magnetization switches by forming two skyrmion lines of opposite chirality, which begin at the wire ends via curling and propagate towards the center. During the propagation of the skyrmion lines, the transformation of the magnetic structure is continuous, but for a full reversal topological point defects, such as Bloch points, need to be created such that the switching becomes irreversible.

MA 54.8 Fri 12:00 H34

Domain walls in square magnetic nanowires - velocity of the Bloch point as a function of temperature — •Kristof M. Lebecki and Dominik Legut — IT4Innovations Centre, VŠB Technical University of Ostrava, Czech Republic

We simulate a magnetic head-to-head domain wall (DW) in an elongated nanowire with a square cross section. Material parameters of the sample resemble permalloy. Cross-section size is selected in such a way that there is a Bloch point in the middle of the DW. The DW has a vortex structure, either right-handed or left-handed - in accordance to the external magnetic field (applied along the wire).

We focus our attention on temperature effects. For that we have implemented the Landau-Lifshitz-Bloch equation in the OOMMF simulation program. Landau-Lifshitz-Bloch equation leads to new effects, for instance magnetization can be locally squeezed. This is especially pronounced in the vicinity of the Bloch point. We consider the influence of temperature on the DW movement, especially the behavior of the Bloch point as a function of temperature. Also, we evaluate the role of the DW helicity. This helps us to test the recent suggestion that Bloch-point mobility drops down with the increase of temperature.

MA 54.9 Fri 12:15 H34

Mechanisms of skyrmion nucleation and annihilation in thin films of chiral magnets — •Pavel Bessarab[1], Gideon Müller[2], Filipp Rybakov[3], Nikolai Kiselev[2], Stefan Blügel[2], Lars Bergqvist[1], and Anna Delin[1] — [1]KTH Royal Institute of Technology, Kista, Sweden — [2]Forschungszentrum Jülich, Jülich, Germany — [3]Institute of Metal Physics, Ekaterinburg, Russia

Theoretical calculations of minimum energy paths (MEPs) for skyrmion nucleation and annihilation in thin films of chiral magnets are presented. MEPs which provide information about the microscopic mechanism and energy barrier of magnetic transitions are identified using a recently developed geodesic nudged elastic band (GNEB) method [1]. The GNEB calculations revealed two mechanisms of the skyrmion annihilation. In ultra-thin films, the MEP corresponds to a radial collapse of the skyrmion. In thicker films, a singularity forms at the film surface and propagates through the film. A maximum is found in the energy barrier for the skyrmion annihilation as a function of film thickness corresponding to a crossover between the two mechanisms. This analysis provides a deeper understanding of skyrmion formation and stability and helps develop ways to control magnetic skyrmions in real nanostructures.

[1] P.F. Bessarab, V.M. Uzdin, H. Jónsson, *Comput. Phys. Commun.* **196**, 335 (2015).

MA 54.10 Fri 12:30 H34

Micromagnetic MuMax3 simulations for different magnetic structures: Coupled layers and core-shell nanotubes — •Thomas Feggeler[1], Ralf Meckenstock[1], Detlef Spoddig[1], Irene Iglesias[2], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Lotharstr. 1, 47057 Duisburg — [2]Institute of Physics and Technology, Immanuel Kant Baltic Federal University, 236004, Nevskogo 14, Kaliningrad, Russia

Simulations of FMR spectra (X-band) of a cobalt stripe ($\sim 1.9\ \mu$m $\cdot \sim 0.5\ \mu$m, thickness: ~ 30 nm) deposited on a permalloy disc (diameter: $\sim 2\ \mu$m, thickness: ~ 30 nm) were performed. Coupling modes due to the exchange interaction between the differently shaped materials are visualized. The simulations were done in support of scanning transmission X-ray microscope measurements with a lateral resolution of 100 nm.

For magnetization measurements on biphase microwires consisting of different core/shell material combinations with a glass coating between the central wire and the outer tube (diameter core: $\sim 20\ \mu$m, diameter core + glass coating: $\sim 30\ \mu$m, total diameter: up to 40 μm, length: ~ 4.5 mm), hysteresis simulations rescaled to nanometer size (diameter core: 20 nm, outer diameter: 40 nm, length: 800 nm) were done. Simulations provide a good match to the experiment and confirm a two-step reversal process with different domain wall nucleation fields for the central wire and the outer tube.

MA 54.11 Fri 12:45 H34

Calculation of GMR effects in granular systems — •Daniel Kappe[1,2], Lisa Teich[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

A macroscopic, semiclassical model was implemented to calculate GMR effects systems which are composed of a non-magnetic matrix and magnetic nanoparticles. There are a couple of publications, which propose models to describe granular systems [1,2]. Those approaches average over all grains and thus do not address the magnetic configuration of the small magnetic particles and clusters of particles. The presented model uses Finite Elements calculations and inputs from micromagnetic simulations [3] to address this issue.

[1] Zhang, Shufeng, and Peter M. Levy. "Conductivity and magnetoresistance in magnetic granular films." Journal of applied physics 73.10 (1993): 5315-5319.

[2] Xing, Lei, and Yia-Chung Chang. "Theory of giant magnetoresistance in magnetic granular systems." Physical Review B 48.6 (1993): 4156.

[3] Teich, Lisa, and Christian Schröder. "Hybrid Molecular and Spin Dynamics Simulations for Ensembles of Magnetic Nanoparticles for Magnetoresistive Systems." Sensors 15.11 (2015): 28826-28841.